OCR ADVANCED SUBSIDIARY GCE
IN GEOLOGY (3884)

OCR ADVANCED GCE
IN GEOLOGY (7884)

Teacher Support: Coursework Guidance

This Teacher Support: Coursework Guidance booklet is designed to accompany the OCR Advanced Subsidiary GCE and Advanced GCE in Geology for teaching from September 2000.

Contents

1 General introduction

This coursework guide has been written to assist teachers in setting suitable coursework tasks and in assessing candidates' work. The guide should be read in conjunction with the specification itself. However, all sections of the specification relating to coursework assessment are included here.

While this guide is concerned with the assessment of coursework, it cannot be emphasised too strongly that before candidates are assessed on their Laboratory and Field Skills, these skills must be taught and candidates must have opportunities to practice and to develop their abilities.

Laboratory and Field Skills are assessed internally by coursework.

Entries are made for Unit 2833 (in AS) or 2836 (in A2). In each of these Units, candidates must take two components - a written paper (Component 01) and a coursework skills assessment (Component 02). Both written paper and skills assessment components must be taken in the same examination session.

In AS Unit 2833, Component 02, marks contribute towards Assessment Objective AO3: Experiment and Investigation.

In A2 Unit 2836, Component 02, marks contribute equally to Assessment Objectives AO3 and AO4: Synthesis of Knowledge, Understanding and Skills. There is assessment of AO4 because:

- candidates are required to use geological knowledge and understanding from other modules of the specification in planning their fieldwork or laboratory work, and in analysing evidence and drawing conclusions;
- in the assessment of all four coursework skills in Unit 2836, Component 02, taken at the end of the course of study, candidates are expected to draw on their experience of such work throughout the course and, in particular, on the outcome of the assessment of these skills in Unit 2833, Component 02.

Coursework provides many opportunities to develop key skills and to collect evidence that may contribute towards the assessment of key skills. Full details are given in Appendix A of the specification and links are identified throughout the content of the specification booklet. Teachers are advised to discuss such opportunities with colleagues and with the students concerned.

2 Coursework Assessment

Unit 2833, Component 02 - Coursework 1 (60 Marks)
Unit 2836, Component 02 - Coursework 2 (60 Marks)

Assessment of candidates' coursework is made by the teacher and moderated externally by OCR.

Skills **P** and **A** are each marked out of 8 and Skills **I** and **E** are each marked out of 7. One mark per skill must be submitted for each candidate for Advanced Subsidiary (Unit 2833, Component 02) and for A2 (Unit 2836, Component 02). Hence, a mark out of 30 is initially calculated for each component. The marks are then doubled so that the final mark submitted for each component is out of 60.

When a skill has been assessed on more than one occasion, in Advanced Subsidiary or in A2, the better or best mark for that skill should be submitted. However, Centres are recommended **not** to assess the skills on more than two occasions in each of Advanced Subsidiary and A2 since this may take up time which might better be devoted to other aspects of the specification.

The skills may be assessed at any time during the course using suitable practical activities, based on laboratory or field work, related to, or part of, the content of the teaching course. The context(s) for the assessment of the coursework for Unit 2833, Component 02 should be drawn from the content of Advanced Subsidiary Units 2831, 2832 and 2833, Component 01; the context(s) for the assessment of the coursework for Unit 2836, Component 02 should be drawn from the content of A2 Units 2834 and 2835, in which the level of demand of the related scientific knowledge and understanding is higher.

In Advanced Subsidiary and in A2, the skills may be assessed in the context of separate practical exercises, although more than one skill may be assessed in any one exercise. They may also be assessed all together in the context of a single 'whole investigation' in which the task is set by the teacher, or by using individual investigations in which each candidate pursues his or her own choice of assignment.

A similar set of mark descriptors is used for both Advanced Subsidiary and A2. These descriptors have been written to provide clear continuity from the assessment of Sc1 in GCSE Science. The difference in standard of Advanced Subsidiary and A2 is a product of the level of demand of the related scientific knowledge and understanding expected and the complexity and level of demand of the tasks set. Also, the mark descriptors for Skills **P** and **A** at A2 include synoptic elements.

Marks submitted for coursework assessment must have been generated from candidates' individual work. Group work is not suitable for assessment unless the work of the individual candidate can be quite clearly identified both by the teacher and the moderator. In some cases it is necessary for candidates to work collectively in order to collect sufficient data for analysis; in these circumstances, planning and implementing should **not** be assessed but the work of candidates may be assessed in analysing and evaluating their results, when they are working independently.

The submission of proposed coursework tasks for approval by OCR is not a requirement of the scheme. However, Centres wishing to obtain guidance on whether a coursework task is suitable, should send details to OCR. Guidance may also be obtained on the marks awarded to candidates' work prior to moderation by sending details of the task set, any background information and marked examples of candidates' work to OCR. Teachers are asked not to send large quantities of material.

A programme of INSET meetings is arranged to provide detailed guidance on coursework assessment. Details are circulated to Centres and a contact number for OCR Training and Customer Support is given in Section 10.

The length of time to be devoted to the assessment of coursework is entirely at the discretion of the teacher. However, it is anticipated that between 5 to 10 hours class time should be sufficient in each of AS and A2.

2.1 Standards at AS and A2

A similar set of assessment descriptors is used for the assessment of coursework in both AS and A2.

Assessments at AS and A2 are differentiated by the complexity of the tasks set and the contexts of the underlying geological knowledge and understanding. In A2, candidates will be required to apply knowledge, understanding and skills from the AS and A2 parts of the specification in planning coursework and in the analysis of results to reach conclusions.

At **AS**, fieldwork or laboratory work is likely to be qualitative or require processing in a context that is familiar to candidates.

1. **Planning** exercises, although novel, focus on apparatus and techniques which have previously been encountered, based on knowledge and understanding from a limited part of the AS specification.
2. **Implementing** involves the manipulation of simple apparatus and the application of easily recognised safety procedures.
3. **Analysing and concluding** involve simple data handling, reaching conclusions based on a limited part of the AS specification.
4. **Evaluation** expects recognition of the main sources of error and direct methods for improving accuracy.

At **A2,** assessments will expect a greater level of sophistication and higher levels of skill.

1. **Planning** exercises require research to provide a satisfactory solution to a problem which can be addressed in more than one way. The underlying knowledge, understanding and skills are likely to be drawn from several different parts of the AS and A2 specifications.
2. **Implementing** involves a detailed risk assessment and the careful use of sophisticated techniques or apparatus to obtain results that are precise and reliable.
3. **Analysing and concluding** involve sophisticated data handling and the synthesis of several strands of evidence. In developing conclusions, candidates will have the opportunity to demonstrate their skills in drawing together principles and concepts from different parts of the AS and A2 specifications.
4. **Evaluation** requires recognition of the key experimental limitations and other sources of error as well as an understanding of the methods that may be used to limit their effect. The evaluation is likely to draw together principles and concepts from different parts of the specification.

2.2 Assessment and Moderation

All coursework is marked by the teacher and internally standardised by the Centre. Marks are then submitted to OCR by a specified date, after which postal moderation takes place in accordance with OCR procedures. The purpose of moderation is to ensure that the standard for the award of marks in coursework is the same for each Centre, and that each teacher has applied the standards appropriately across the range of candidates within the Centre.

Coursework submissions should be clearly annotated by the Centre to support the marks awarded to the candidates.

The sample of work that is submitted to the Moderator for moderation must show how the marks have been awarded in relation to the marking criteria.

2.3 Minimum Coursework Requirements

If no work is submitted by a candidate for a coursework component, the candidate should be indicated as being absent from that component on the coursework mark sheets submitted to OCR. Any work submitted by a candidate should be assessed according to the mark descriptors and marking instructions and the appropriate mark awarded, which may be 0 (zero).

2.4 Authentication of Coursework

As with all coursework, the teacher must be able to verify that the work submitted for assessment is the candidate's own. Sufficient work must be carried out under direct supervision to allow the teacher to authenticate the coursework marks with confidence.

2.5 Special Arrangements for Coursework

For candidates who submit some coursework but are unable to complete the full assessment, or whose performance may be adversely affected through no fault of their own, teachers should consult the *Inter-Board Regulations and Guidance Booklet for Special Arrangements and Special Consideration*. In such cases, advice should be sought from OCR as early as possible during the course.

2.6 Differentiation

In coursework, differentiation is by task and by outcome. Candidates will undertake assignments which enable them to display positive achievement.

2.7 Some definitions

Hypothesis

An hypothesis is a model, based on scientific knowledge and understanding, proposed to explain a particular problem or a set of observations or measurements. Having devised an hypothesis, it is possible to make predictions based on it, and these can be tested by experiment.

The ‘scientific method’ is based on the idea that an hypothesis can be disproved by experiment (when predictions are found to be untrue) but can never be proved (since an experimenter may, in the future, disprove it). Thus, an hypothesis which is not disproved remains in place and, when it has general acceptance, may come to be called a theory or law.

Accuracy

The accuracy of an observation or measurement is the degree to which it approaches a notional ‘true’ value or outcome.

The accuracy of an observation or measurement depends on the laboratory or fieldwork techniques used, the skill of the experimenter and the equipment (including measuring instruments) used. Removing or minimising sources of error improves accuracy and the degree of accuracy can be estimated by evaluating sources of error (either qualitatively or quantitatively as appropriate).

Precision is here taken as being that part of accuracy which is wholly in the hands of the experimenter. So, having devised a laboratory or fieldwork technique and selected the apparatus, the experimenter may choose to take observations or measurements to different degrees of precision (or may do so through lack of skill or carelessness). Decisions about the precision with which observations or measurements are made may take into account the nature of the investigation and an assessment of the sources of error. For example: a low-power drawing from a microscope may address the task set; there may be little point in measuring a quantity to four significant figures if other quantities are measured to two significant figures.

Reliability

Reliability is a measure of the confidence that can be placed in a set of observations or measurements. The closer a set of observations or measurements approaches to conformity with an underlying model, process, structure etc. (which may be known or unknown), the more reproducible it is likely to be.

If the underlying model, process or structure is known, or a suitable hypothesis can be drawn up, reliability can be judged by reference to this. So, for example, the distance between data points and the line of a graph may provide evidence of reliability and statistical techniques may be used to provide a quantitative assessment of reliability in such cases. If observations or measurements are replicated, then the closeness of the replicates provides another way of judging reliability.

The reliability of a set of observations or measurements depends on the number and accuracy of the individual observations or measurements. Replicating observations or measurements increases the reliability of the set.

Validity

The validity of a conclusion is a measure of the confidence that can be placed in it. The validity of a conclusion depends upon factors such as the range and reliability of the observations or measurements that underpin it, any assumptions made in developing hypotheses or planning the investigation, and the nature of the investigation itself.

A conclusion may relate to whether or not a proposed hypothesis can be rejected or accepted. In such cases statistical techniques may be used to place a value on the reliability of data by generating a probability that the data do conform with the hypothesis. Such techniques should be used where appropriate.

3 Introduction to each skill

The Skills

The Laboratory and Field Skills to be assessed are:

Skill P Planning

The Geology Specification states that candidates should:

- identify and define the nature of a question or problem using available information and knowledge of geology;
- retrieve and evaluate information from multiple sources (including computer databases where appropriate) and deciding the measurements and observations likely to generate useful and reliable results;
- choose effective and safe procedures, selecting appropriate apparatus and materials, and consider ethical implications and environmental and safety aspects of the proposed procedures.

To achieve these objectives and satisfy the full demands of the mark descriptors for this skill, candidates will benefit by providing evidence that they can:

1. identify and define a problem capable of investigation and describe its geological context;
2. plan a fair test or practical procedure, identifying the equipment required and making predictions where appropriate;
3. identify key factors to vary, control or take account of and select a suitable number and range of observations and/or measurements;
4. use and evaluate information from a variety of sources to develop and justify an appropriate strategy;
5. take into account the need for safe working and accurate and reliable data collection;
6. use appropriate geological terminology and write up their plan ensuring correct spelling, punctuation and grammar.

For candidates to be able to achieve the highest marks for this skill, tasks set must be sufficiently open-ended to allow more than one solution. The tasks must provide opportunities for candidates to gather information from a variety of sources (including perhaps text books, the Internet, preliminary work) to inform their plans and the geological knowledge and understanding underpinning their work should be of a high standard.

For each task, it is suggested that candidates are asked to complete a preliminary plan which is assessed by the teacher, primarily to ensure that it is practicable and safe. The final mark awarded for planning should, however, take into account any additional work done during the implementation of the plan, i.e. to include any modifications or additions. Planning must be carried out individually and experience shows that candidates achieve higher marks if they carry out their plan.

Skill **P** may be assessed as part of a 'whole investigation' or with Skill **I** and/or Skills **A** and **E**.

At A2, there are additional statements that relate to synoptic assessment to take into account in the assessment. Thus, to achieve the highest marks, the tasks set must offer opportunities for candidates to make use, in their planning, of geological knowledge and understanding from both AS and A2 modules.

Skill I Implementing

This skill involves implementing the plan created under Skill P, or if assessed by a separate exercise, implementing a plan created by teaching staff. The Geology Specification states that candidates should:

- use apparatus and materials in an appropriate and safe way;
- carry out work in a methodical and organised way with due regard for safety and with appropriate consideration for the well-being of living organisms and the environment;
- make and record detailed observations in a suitable way, and make measurements to an appropriate degree of precision, using IT where appropriate.

To achieve these objectives and satisfy the full demands of the mark descriptors for this skill, candidates will benefit by providing evidence that they can carry out data gathering techniques and procedures:

1. safely;
2. competently;
3. accurately;
4. systematically.

Candidates are expected to provide evidence that they can record observations and measurements:

5. clearly (e.g. a spreadsheet or table);
6. accurately;
7. systematically;
8. with an appropriate level of detail;
9. in an appropriate format (e.g. spreadsheets, tables, etc).

Candidates are advised to make appropriate use of ICT techniques where these will allow objectives to be achieved more effectively.

For candidates to achieve the highest marks for this skill, the techniques used should be familiar and well understood. The tasks set should require precision and skill and that make sufficient demands on a candidate's ability to use a variety of data gathering techniques, procedures, and methods of recording observations and measurements.

Skill **I** may be assessed as part of a 'whole investigation', in isolation, or in combination with Skills **P** and/or **A**.

Skill A Analysing Evidence and Drawing Conclusions

This skill involves analysing data collected under Skill I, or if assessed by a separate exercise, analysing data provided by teaching staff or from secondary sources. The Geology Specification states that candidates should:

- present geological information and ideas in appropriate ways, including tabulation, line graphs, histograms, continuous prose, annotated drawings and diagrams, using geological nomenclature and terminology;
- recognise and comment on trends and patterns in a set of data or information, identify sources of error or limitations of measurements, and show an understanding of the concept of statistical significance where appropriate;
- draw valid conclusions by applying scientific knowledge and understanding.

To achieve these objectives and satisfy the full demands of the mark descriptors for this skill, candidates will benefit by providing evidence that they can:

1. process and present data collected during investigations in an appropriate format (e.g. spreadsheets, charts, etc);
2. use a variety of graphical and numerical techniques where appropriate (e.g. charts, statistical techniques, etc);
3. use geological terminology correctly and write up work ensuring correct spelling, punctuation and grammar;
4. identify trends or patterns from the evidence collected and draw appropriate conclusions;
5. explain conclusions with reference to associated scientific knowledge and understanding.

Candidates are advised to make appropriate use of ICT techniques where these will allow objectives to be achieved more effectively.

For candidates to achieve the highest marks in this skill, the tasks set must provide sufficient data or information to make the analysis demanding, and allow them to relate their results to geological knowledge and understanding of a high standard.

Skill **A** may be assessed as part of a 'whole investigation', in isolation, or in combination with Skills **I** and/or **E**.

At A2, there are additional statements that relate to synoptic assessment to take into account in the assessment. Thus, to achieve the highest marks, the tasks set must offer opportunities for candidates to make use, in their analysis, of geological knowledge and understanding from both AS and A2 modules.

Skill E Evaluating Evidence and Procedures.

This skill involves evaluating the data collected under Skill **I**, the procedures and plan formed under Skill **P** (or provided by teaching staff), and the outcomes of analysis conducted under Skill **A**. The Geology Specification states that candidates should:

- assess the reliability and precision of laboratory/field data and the conclusions drawn from it;
- evaluate the techniques used in the laboratory/field activity, recognising their limitations.

To achieve these objectives and satisfy the full demands of the mark descriptors for this skill, candidates will benefit by providing evidence that they can:

1. recognise any anomalous results and suggest reasons for them;
2. assess the accuracy and reliability of the data;
3. identify and assess the limitations of the techniques used and strategy followed and relate these to sources of error;
4. suggest and justify how the techniques used and strategy followed might be improved;
5. assess the significance of uncertainties in the evidence in terms of their effect on the final conclusions drawn.

For candidates to achieve the highest marks in this skill it is advisable that they either carry out the investigation themselves or have seen the techniques demonstrated. Only in this way will they be able to evaluate experimental and fieldwork procedures effectively. The tasks set should be sufficiently complex to allow detailed analysis and the data or information collected should permit evaluation of error and reliability. There should also be the opportunity to suggest realistic changes to the procedures used that would improve the quality of the results.

Skill **E** is best assessed as part of a 'whole investigation', or together with Skill **A**, in which case the experimental or fieldwork procedure should have been carried out by the candidates themselves, or demonstrated to them. Where the experimental or fieldwork procedures are such that individual working is not possible, candidates could carry out the investigation working in groups but then be assessed for Skills **A** and **E** on their individual work.

Assessing this skill on its own is **not** recommended.

4 Notes for Guidance on Coursework Submission and Assessment

These notes are intended to provide guidance for teachers in assessing coursework skills, but should not exert an undue influence on the methods of teaching or provide a constraint on the practical work undertaken by candidates. It is not expected that all of the practical work undertaken by candidates would be appropriate for assessment.

It is expected that candidates will have had opportunities to acquire experience and develop the relevant skills before assessment takes place.

4.1 The Demand of an Activity

The demand of an activity is an important feature of the assessment. From the bottom to the top of the mark range in a skill area the activity should involve increasing demands of associated geological knowledge and understanding, manipulation, precision and accuracy and complexity.

The difference in standard of Advanced Subsidiary and A2 is a product of the level of demand of the related geological knowledge and understanding, together with the complexity and level of demand of the tasks set. In A2, candidates will be required to apply knowledge, understanding and skills from the AS and A2 parts of the specification in planning laboratory work or fieldwork and in the evaluation of data (synoptic assessment).

Teachers should appreciate that the choice of an activity that is comparatively undemanding (primarily in terms of the level of the geological knowledge and understanding that can be linked to the activity, and in the range/complexity of the equipment/techniques used) may prevent access to the highest marks.

Teachers should be aware of this feature of the assessment so that, when considering the award of higher marks, the activity should require a sophisticated approach and/or complex treatment. Higher marks must not be awarded for work that is simplistic or trivial.

One of the factors that determine the demand of an activity is the level of guidance given to candidates. The use of a highly structured worksheet, for example, will reduce the number of decisions and judgements required by the candidate and will limit the range of marks available.

In each of AS and A2, the time required for internal assessment is normally expected to be between five and ten hours in total, the majority of which will be supervised laboratory/field time.

4.2 Marking Candidates' Work

A similar set of mark descriptors is used for Advanced Subsidiary and A2. The descriptors should be used to make a judgement as to which mark best fits a candidate's performance.

The descriptors have been written to provide clear continuity from the assessment of Sc1 for GCSE. This should ensure an effective continuation of the development of candidates' skills from GCSE to Advanced Subsidiary and A Level.

The mark descriptors within a skill area have been written to be hierarchical. Thus, in marking a piece of work, the descriptors for the lowest defined mark level should be considered first and only if there is a good match should the descriptors for the next level up be considered. Therefore, if a teacher is considering awarding a high mark for a piece of work, the work must have demonstrated a good match to all the lower mark descriptors.

For each skill, the scheme allows the award of intermediate marks (between the defined mark levels). An intermediate mark may be awarded when the work of a candidate exceeds the requirements of a defined mark level but does not meet the requirements of the next higher defined mark level sufficiently to justify its award. Thus, an intermediate mark could be awarded if the work meets only one of the two descriptors at the higher defined mark level, or provides a partial match to both descriptors, or provides a complete match to one and a partial match to the other.

In Skills **P** and **A**, a mark above the highest defined mark level should be awarded for work which meets all the requirements of the descriptors for the highest defined mark level, and is judged to be of exceptional merit in terms of originality, depth, flair, or in the use of novel or innovative methods.

A mark of zero should be awarded where there has been an attempt to address the skill but the work does not meet the requirements of the lowest defined mark level.

The marks awarded should be based on both the final written work and on the teacher's knowledge of the work carried out by the candidate. In assigning a mark, attention should be paid to the extent of any guidance needed by, or given to, the candidate.

4.3 Synoptic Assessment

Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the Advanced GCE course. Assessment Objective AO4 relates specifically to synoptic assessment and marks from the A2 Coursework Skills Unit, 2836, Component 02, contribute to the assessment of AO4.

During laboratory work and fieldwork, synoptic assessment:

- allows candidates to apply knowledge and understanding of principles and concepts from different parts of the specification in planning experimental laboratory work and fieldwork and in the analysis and evaluation of data;
- allows candidates to apply skills and techniques learned during the course.

All practical work assessed internally by Centres for the **A2** Unit 2836, Component 02 should draw on the range of experience that the candidate has acquired during the AS and A2 courses. It is particularly important that an exercise used to assess planning skills should involve an element of research which goes beyond the repetition of an experiment that simply reflects the use of ideas or techniques met within the module currently being studied. Likewise, an assessment involving analysing evidence and drawing conclusions must require a candidate to use knowledge and understanding acquired outside the confines of a standard experiment recently practised. During the process of moderation, evidence will be sought that such breadth has been achieved.

The assessment descriptors for the skills of Planning (**P**) and Analysing Evidence and Drawing Conclusions (**A**), include statements that relate specifically to synoptic assessment. These are shown in bold and should be applied only when assessing A2 work. Thus, in A2, a candidate will not be able to achieve more than 2 marks in each of Skills **P** and **A** without demonstrating aspects of synoptic assessment. Candidates will also bring to the assessment of Skill **I** (Implementing) their experience of practical and investigative work from throughout the course. In Skill **E** (Evaluating Evidence and Procedures), aspects of Skills **P** and **A** are evaluated. Overall, in A2, approximately 15 of the 30 available marks can thus be identified as contributing to an assessment of AO4 (synoptic assessment).

4.4 Quality of Written Communication

Coursework must include an assessment of candidates' quality of written communication. At Level 3, candidates are required to:

- select and use a form and style of writing that is appropriate to the purpose and complex subject matter;
- organise relevant information clearly and coherently, using specialist vocabulary when appropriate;
- ensure the text is legible and that spelling, grammar and punctuation are accurate, so that the meaning is clear.

The mark descriptors for Skills **P** and **A** have been written to include these aspects, and these skills carry an additional mark each in recognition of this.

4.5 Annotation of Candidates' Work

Each piece of assessed coursework must be annotated to show how the marks have been awarded in relation to the relevant skills.

The writing of comments on candidates' work can provide a means of dialogue and feedback between teacher and candidate, and a means of communication between teachers during internal standardisation of coursework. The main purpose of annotating candidates' coursework should be, however, to provide a means of communication between the teacher and the Moderator, showing where marks have been awarded and why. The sample of work which is submitted for moderation must show how the marks have been awarded in relation to the marking criteria.

Annotations should be made at appropriate points in the margins of the text. The annotations should indicate both where achievement for a particular skill has been recognised, and where the mark has been awarded. It is suggested that the minimum which is necessary is that the 'shorthand' mark descriptors (for example, **P**.5a, **I**.3b) should be written at the point in the text where it is judged that the work has met the descriptors concerned.

For Skill **I**, Implementing, more detail is necessary and the Moderator will require evidence concerning candidates' use of practical techniques and safe working practice. This evidence could take the form of checklists or written notes.

4.6 Health and Safety

Geological coursework can be carried out in the field or in the laboratory. The comments in the following paragraphs outline general health and safety issues for all sciences. Geology teachers will probably find many of the documents referred to in their institution's Science Department. Advice on geological fieldwork follows later in this section.

In UK law, health and safety is the responsibility of the employer. For most establishments entering candidates for Advanced Subsidiary GCE and Advanced GCE this is likely to be the education authority or the governing body. Employees, i.e. teachers and lecturers, have a duty to co-operate with their employer on health and safety matters.

Various regulations, but especially the COSHH Regulations 1996 and the Management of Health and Safety at Work Regulations 1992, require that before any activity involving a hazardous procedure or harmful micro-organisms is carried out, or hazardous chemicals are used or made, the employer must provide a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found in Chapter 4 of *Safety in Science Education* (see below). For members, the CLEAPSS guide, *Managing Risk Assessment in Science* offers detailed advice.

Most education employers have adopted a range of nationally available publications as the basis for their Model Risk Assessments. Those commonly used include:

Safety in Science Education, DfEE, 1996, HMSO, ISBN 0 11 270915 X;

Safeguards in the School Laboratory, 10th edition, 1996, ASE ISBN 0 86357 250 2;

Hazcards, 1995, CLEAPSS School Science Service*;

Laboratory Handbook, 1988-97, CLEAPSS School Science Service*;

Topics in Safety, 2nd edition, 1988, ASE ISBN 0 86357 104 2;

Safety Reprints, 1996 edition, ASE ISBN 0 86357 246 4.

* Note that CLEAPSS publications are only available to members or associates.

Where an employer has adopted these or other publications as the basis of their model risk assessments, an individual school or college then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment. Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate, or that the skills of the candidates were insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded, for example on schemes of work, published teachers guides, work sheets, etc. There is no specific legal requirement that detailed risk assessment forms should be completed, although a few employers require this.

Where project work or individual investigations, sometimes linked to work-related activities, are included in specifications these may well lead to the use of novel procedures, chemicals or micro-organisms, which are not covered by the employer’s model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting the CLEAPSS School Science Service (or, in Scotland, SSERC).

When candidates are planning their own practical activities, whether in project work or for more routine situations, the teacher or lecturer has a duty to check the plans before practical work starts and to monitor the activity as it proceeds.

4.7 Fieldwork Code of Practice

Teaching staff intending to lead field trips should note that they have particular responsibilities for ensuring the safety of those participating in the fieldwork and for ensuring that no damage is caused to property or injury or loss to third parties. Read carefully and follow the Code for Geological Field Work issued by the Geologist's Association. The leaflet provides guidelines on best practice in general geological fieldwork, specimen collecting, visiting quarries and field-based research. It is obtainable from the Geologists' Association, Burlington House, Piccadilly, London W1V 9AG.

The Code of Practice for Geological Visits to Quarries, Mines and Caves, issued by the Institute of Geologists, is also very useful if such localities are to be used.

The following code is a summary of the Rules of Geological Fieldwork presented in Earth Heritage Conservation published by the Geological Society in association with the Open University (1994; ISBN 1 897799 03 9).

- Always remember that fieldwork is potentially hazardous: the quarries, excavations and cliffs that so often provide the best exposures for study are also inherently dangerous places.
- Don't visit any field site without obtaining the prior permission of the owner. Bear in mind that you may need a guide to conduct you round a working quarry. Never enter a working quarry without first visiting the quarry office.
- Don't do fieldwork by yourself if working in uninhabited or remote areas. Leave others with information of your intended route and don't depart from your plan.
- Wear strong and waterproof footwear with non-slip soles.
- Always carry warm and waterproof clothing if you plan to spend several hours in the field.
- Wear a hard hat when working near steep faces.
- Be aware that rock falls and collapses of sand and gravel faces can occur at any time and without prior warning.
- Use your geological hammer sparingly, and only at sites where hammering is permitted. Never hammer rocks without wearing protective glasses or goggles.
- Don't visit coastal sites without checking on tide times. Ensure that you have a means of retreat if caught on a rising tide.
- Do not climb on steep faces. Use binoculars to study rocks when they are too dangerously situated to be approached safely.
- Take sensible safety precautions at all times - always carry appropriate safety equipment, including a compass, and a First Aid kit.

Further advice may be found in the Safety in Geoscience Fieldwork: Precautions, Procedures & Documentation (1996), published by The Geological Society and developed jointly with the Committee of Heads of University Geoscience Departments.

5 Mark Descriptors for the Coursework Skills

In defining the various mark descriptors, it is recognised that practical tasks vary widely, both in the procedures used and in the nature of the observations and measurements which may be made by the candidate. The mark descriptors within each defined level are intended to provide guidance to teachers on how to recognise levels of achievement. It is acknowledged that the balance between the statements provided for a particular level of performance will vary with the nature of the activity. Whilst both statements for a particular level must be considered in awarding the marks, it is clear that teachers will need to judge for themselves the relative weightings they attach to each of the statements.

Both statements at a defined level must be satisfied in order that the mark for this level is awarded. All descriptors for lower defined levels must be satisfied before a higher mark is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, manipulation, precision, accuracy and complexity.

The text in italics, which follows each statement, gives examples of how the statement may be interpreted with respect to geology coursework.

Skill P - Planning Total 8

Mark Descriptor

The candidate:

1 **P.1a** develops a question or problem in simple terms and plans a fair test or an appropriate practical procedure, making a prediction where relevant.

'Simple terms' implies no significant attempt to identify any particular objectives, or relate the investigation to geological theory.

P.1b chooses appropriate equipment.

I.e. simply states the methods and equipment to be used, e.g. measurement of dip using a clinometer or weighing of sieved sediments using an electronic balance.

2

3 **P.3a** develops a question or problem using scientific knowledge and understanding **drawn from more than one area of the specification**; identifies the key factors to vary, control or take account of.

'Key factors' in the field may include dip, strike, rock type, grain size, sedimentary structures, fossil content, etc. In the laboratory, time, weight and temperature might be examples.

P.3b decides on a suitable number and range of observations and/or measurements to be made.

Observations and measurements should related to the 'key factors' identified in 3a, e.g. for rock descriptions the range might include grain size, roundness, sorting, composition, colour, fossil content, etc. A 'suitable number' may be the number of measurements of dip made before an average is established, or how many specimens of a rock type should be used as a basis for identification and description.

4

5 **P.5a** uses detailed scientific knowledge and understanding **drawn from more than one module of the specification** and information from preliminary work or a secondary source to plan an appropriate strategy, taking into account the need for safe working and justifying any prediction made;

Secondary sources may simply be textbooks, BGS maps, material derived from CD-ROMs, the Internet, etc. All investigations should include a basic risk assessment and a brief account of the measures taken to ensure safety.

P.5b describes a strategy, including choice of equipment, which takes into account the need to produce precise and reliable evidence; produces a clear account and uses specialist vocabulary appropriately.

The 'overall strategy' encapsulates all the steps within the plan of action, including the their purpose, order, timing, methods, etc. Plans should include a sequential list of tasks arranged in a logical order, with a description of each.

6

7 **P.7a** retrieves and evaluates information from a variety of sources, and uses it to develop a strategy which is well structured, logical and linked coherently to underlying scientific knowledge and understanding **drawn from different parts of the AS and A2 specification**; uses spelling, punctuation and grammar accurately.

A higher level of sophistication is required here. The various approaches and interpretations found in secondary resources need to be accounted for and evaluated before the plan is finalised. This may involve being aware of several possible outcomes, while still at the planning stage.

P.7b justifies the strategy developed, including the choice of equipment, in terms of the need for precision and reliability.

Justification should explain why the particular strategy and methods selected might be expected to lead to precise and reliable results, in relation to alternative approaches.

8 Satisfies all the descriptors up to 7b with ease, producing very high order work

The statements in bold represent additional requirements when assessing A2 work; they are not to be used at AS.

Skill I - Implementing Total 7

Mark	**Descriptor**	
		The candidate:
1	**I.1a**	demonstrates competence in simple techniques and an awareness of the need for safe working.
		Simple techniques, e.g. measurements of dip, bed thickness, crystal size, weighing sieved sediments, etc. Basic safety comments on fieldwork hazards and laboratory hazards where appropriate.
	I.1b	makes and records observations and/or measurements which are adequate for the activity.
2		
3	**I.3a**	demonstrates competence in practised techniques and is able to manipulate materials and equipment with precision.
		Competent use in the laboratory or field of equipment, e.g. compass-clinometer, electronic balances, thermometers, etc; and techniques, e.g. description and identification of geological structures and materials such as minerals, rocks and fossils. Production of a valid and accurate dataset.
	I.3b	makes systematic and accurate observations and/or measurements which are recorded clearly and accurately.
		Employs a systematic approach to data collection in laboratory or field, for example, in rock descriptions, graphic logging. Field sketches, photographs and drawings are labelled and titled. Numeric data is neatly recorded in tabular form.
4		
5	**I.5a**	demonstrates competence and confidence in the use of practical techniques; adopts safe working practices throughout.
		Uses practical techniques effectively to produce a valid and accurate data set without significant teacher intervention. Hazards and strategies for handling them are well explained and followed.
	I.5b	makes observations and/or measurements with precision and skill; records observations and/or measurements in an appropriate format
		Collects accurate and relevant data and records it in a logical detailed manner; sketches, photographs and drawings are well labelled and titled and accompanied by a sensible scale and show most of the significant geological features present. Tables have clear titles and measurements are recorded in the correct units
6		
7	**I.7a**	demonstrates skilful and proficient use of all techniques and equipment.
		Uses practical techniques very effectively to produce a valid, detailed and accurate data set.

I.7b makes and records all observations and/or measurements in appropriate detail and to the degree of precision permitted by the techniques or apparatus.

Records all data in detail in a well structured manner using appropriate techniques and making accurate use of geological terminology; sketches, photographs and drawings are detailed, well labelled and titled and accompanied by a sensible scale and show all the significant geological features. A brief account of any problems in data collection is given and gaps in the data are explained.

Skill A - Analysing Evidence and Drawing Conclusions Total 8

Mark Descriptor

The candidate:

1 **A.1a** carries out some simple processing of the evidence collected from experimental work (*i.e. laboratory work or fieldwork*).

Carries out simple processing, e.g. basic reorganisation of data into a neater more readable format.

A.1b identifies trends or patterns in the evidence and draws simple conclusions.

Identifies, for example, changing dip directions and amounts and concludes the presence of a fold, or in crystallisation simulations, simply notes that crystals which form quickly are smaller, etc.

2

3 **A.3a** processes and presents evidence gathered from experimental work (i.e. laboratory work or fieldwork) including, where appropriate, the use of appropriate graphical and/or numerical techniques.

Processes and presents data collected in the field, including, for example simple histograms, bar charts, rose diagrams, totals and averages. A more complex re-organisation of data occurs which involves, for example, grouping data into categories.

A.3b links conclusions drawn from processed evidence with the associated scientific knowledge and understanding **drawn from more than one area of the specification**.

E.g. relates the presence of a fold to the stress directions which produced it, or the presence of an unconformity with a period of uplift and erosion prior to resumed deposition, or explains that only small crystals are possible when cooling is rapid and links this to chilled margins.

4

5 **A.5a** carries out detailed processing of evidence and analysis including, where appropriate, the use of advanced numerical techniques such as statistics, the plotting of intercepts or the calculation of gradients.

E.g. relates the presence of a fold to the stress directions which produced it, or the presence of an unconformity with a period of uplift and erosion prior to resumed deposition, or explains that only small crystals are possible when cooling is rapid and links this to chilled margins.

A.5b draws conclusions which are consistent with the processed evidence and links these with detailed scientific knowledge and understanding **drawn from more than one module of the specification**; produces a clear account which uses specialist vocabulary appropriately.

E.g. relates the style folding to the rock type and the likely stresses and temperatures involved; or the timing of an unconformity based on evidence of the ages of the enclosing rocks; or explains the variation of crystal size and texture in crystallisation simulations and relates this to the variations which occur in intrusions.

6

7 **A.7a** where appropriate, uses detailed scientific knowledge and understanding **drawn from different parts of the AS and A2 specification** to make deductions from the processed evidence, with due regard to nomenclature, terminology and the use of significant figures (where relevant).

E.g. makes deductions about the geological history of an area using graphic logs, geological cross sections or maps created from data collected in the field; or makes appropriate deductions about the origin of sediments based on the results of grain size, sorting, skewness, analysis of composition, roundness and fossil content.

A.7b draws conclusions which are well structured, appropriate, comprehensive and concise, and which are coherently linked to underlying scientific knowledge and understanding **drawn from different parts of the AS and A2 specification**; uses spelling, punctuation and grammar accurately.

E.g. concisely and accurately identifies a range of possible interpretations of the evidence and establishes the probability of each with reference to geological knowledge and understanding.

8 Satisfies all the descriptors up to 7b with ease, producing very high order work

The statements in bold represent additional requirements when assessing A2 work; they are not to be used at AS.

Skill E - Evaluating Evidence and Procedures Total 7

Mark Descriptor **The candidate:**

1 **E.1a** makes relevant comments on the suitability of the *experimental (i.e. laboratory work or fieldwork)* procedures.

Makes relevant comments on the suitability of the methods used in laboratory and field exercises

E.1b recognises any anomalous results.

This may apply to some laboratory-based work, but less so to field exercises. There may not be any anomalous results

2

3 **E.3a** recognises how limitations in the experimental (i.e. laboratory or field) procedures and/or strategy may result in sources of error.

E.g. deductions about the mineral composition of finer grained rocks in hand specimen; limited number of measurements and observations that can be made in the time available; effects of the weather and poor exposure on fieldwork; imperfections of sieving, and inaccuracies in weighing, timing, sampling, assessing temperatures, etc.

E.3b comments on the accuracy of the observations and/or measurements, suggesting reasons for any anomalous results.

E.g. limited accuracy in assessment of grain/crystal size using a hand lens; explains how the limitations listed under 3a cause inaccuracies.

4

5 **E.5a** indicates the significant limitations of the experimental (i.e. laboratory or field) procedures and/or strategy and suggests how they could be improved.

E.g. samples of rock could be collected and thin sections made; further time could be made available to enable a more comprehensive (and representative) set of data to be collected; visits might be arranged at a more appropriate time. The suggestions do not need to be limited to what candidates could carry out in a school or college context.

E.5b comments on the reliability of the evidence and evaluates the main sources of error.

E.g. discusses the limited validity of field data from locations where exposure is interrupted by vegetation or access is restricted. 'Evaluation' should involve assessing the degree of error resulting from limitations in the techniques and equipment used.

6

7 **E.7a** justifies proposed improvements to the (i.e. laboratory or field) procedures and/or strategy in terms of increasing the reliability of the evidence and minimising significant sources of error.

E.g. explains how and why the improvements suggested in 5a will improve the reliability of the data.

E.7b assesses the significance of the uncertainties in the evidence in terms of their effect on the validity of the final conclusions drawn.

E.g. discusses a variety of possible interpretations of laboratory or field data in situations where analysis of raw and processed data does not produce totally conclusive results.

6 Frequently asked questions (FAQs)

1 Can a single coursework exercise be used to assess more than one skill?

Yes, skills may be assessed separately or in combination. All four skills can be tested at any one time, in a 'whole investigation'. However, it is the responsibility of candidates and their centres to ensure that it is clear where each skill is being covered. This should be achieved by the use of titles and sub-titles, which relate to the assessment criteria associated with each skill.

2 Is it advisable to test more than one skill in any one exercise?

*This depends very much on the nature of the task and how it is set up. Generally, candidates achieve higher marks for planning if they are able to perform their investigation since this gives them opportunities to revise the plan in the light of experience. Thus, Skills **P** and **I** are often assessed together. Similarly, candidates who have not planned and carried out an investigation (or at least seen it demonstrated) will find it difficult to evaluate the investigation. Skill **E** may, therefore, be better assessed in a whole investigation. If all four skills are to be tested in one 'whole investigation', it is essential that it is clear to Moderators, by means of titles, subtitles, teachers' comments, etc., which are being tested where. Most candidates cope quite well covering two skills on one exercise, provided they are issued with worksheets with instructions which relate to the required assessment criteria.*

3 Is it better to do fieldwork or laboratory work?

Assessment exercises can be based on either approach. In practice, many Centres may find that a mixture of the two will offer greater flexibility.

4 Is there any size or word limit on coursework submissions?

No, but there is absolutely nothing to be gained by submitting particularly large volumes of work for each assessment, especially where the same technique is repeated several times. Moderators will be looking at the quality of the work rather than the quantity and clear evidence that candidates have achieved the criteria listed under each skill.

5 Do Centres need to show evidence of marking on candidate's work?

Yes; the minimum requirement is that the 'shorthand' mark descriptors (e.g. P.3b or A.5a) are written in the margin of the script at the point where the work has met the descriptors concerned. However, the more comments clearly written on submitted work, the easier it is for Moderators to judge whether candidates have been fairly assessed.

6 Do Centres need to submit copies of the worksheets, exercises and resources given to students?

Yes; Moderators need to know exactly what candidates were asked to do, and what help they received.

7 Do Centres need to submit mark schemes?

*The general descriptors given in the specification (and in Section 5) may be used directly by centres to mark candidates' work. However, centres may choose to develop specific sets of descriptors for particular tasks, to allow consistency of marking from year to year, and from teacher to teacher. If such 'contextualised' descriptors are used, they must be very closely based on the standard descriptors and they must be sent to the moderator with the sample of work. It should be noted that the Moderator will mark using the general set of descriptors (given in the specification), to ensure that the standard of work is the same from centre to centre. For Skill **I**, teachers should provide details of the aspects of the work that were scrutinised, in the form of checklists or written notes and details of correct measurements and observations would be helpful.*

8 Some candidates find aspects of coursework (e.g. Skill **P**) very difficult. What advice can you offer which will increase candidates' prospects of achieving good marks?

It is clearly important that candidates are taught the skills and given opportunities to practice, before being assessed. Candidates may find it helpful if staff go through a worked exemplar showing how they themselves would tackle a particular topic, provided that candidates are not allowed to produce work on the same topic for submission. Candidates should be made aware of the descriptors used to assess their work, so that they can ensure that all aspects of the descriptors are addressed. Worksheets with instructions closely related to the requirements of the skill, give considerable assistance to candidates. However, if they are too specific, they may stifle candidates' opportunities for innovation and reduce their access to the highest marks, so they should be used carefully.

9 Do all candidates have to do completely different topics for Skill **P** assessments?

*Not exactly; Centres may ask all their candidates to produce Skill **P** work on one particular topic, e.g. investigating the origin of sediments, producing a small scale geological map in the field, etc., but completion of all the assessment criteria within the Skill must be carried out on an individual basis.*

10 How can Skill **P** be used with fieldwork exercises when the candidates may not have been to the specific field location before?

Teaching staff can give their candidates information about the field location in advance of the trip, e.g. geological maps, photographs, etc. A lesson may be taught to give background information on the area. The only proviso is that candidates are not given answers, interpretations, etc., to possible areas of investigation. Again, a well-designed work sheet will help.

11 In Skill **P** work, do candidates have to put their plans into action and examine the results in order to evaluate and modify their plans?

Not officially, but candidates who do not have the opportunity to carry out their plans and modify them in the light of experience will be at a considerable disadvantage and there are few other ways of carrying out a proper evaluation. For this reason, it is very helpful if Skill P is tested along with at least one of the other skills.

12 I am having trouble deciding whether my exercises properly address the demands of the skills listed in the specification. What advice is available?

A proposed task may be submitted to OCR and a response on its suitability will be provided. A contact address is given in Section 10. INSET courses are provided each year; details are sent to Centres, and a contact address for the Training and Customer Support section is also given in Section 10.

13 None of my candidates have produced work that is as good as the best exemplars in this guide. Does this mean they cannot achieve full marks for their assessments?

No. As long as candidates' work meets all the mark descriptors, including the top band, there is no reason why full marks should not be awarded. There can be a big range of performances within the top band. If you have one or two brilliant students, do not let this persuade you that those who are only 'very good' must be worth less than full marks. Conversely, if all your candidates are of more limited ability, do not be misled into giving the best of them full marks.

14 Can candidates use the Internet during their investigations?

*Yes; there is some excellent material available and the highest mark descriptors for Skill **P** require candidates to draw together material from several sources. All URLs should be listed (with any other sources) in a bibliography. It should be noted that unless this information is processed or modified in some way and used in the development of the strategy, it is unlikely to be worthy of credit.*

15 Will candidates improve their chances of achieving high marks by making extensive use of Information and Communication Technology in their reports?

Computer generated material is not in itself worth any more marks than hand-written work. However, if the use of ICT enables the mark descriptors for any of the skills to be more effectively addressed, then candidates could gain extra credit. It should be noted that many graph-plotting packages, if not used expertly, may not produce the most appropriate graphs.

16 My candidates have completed several assessments in a field notebook that includes some unassessed work. Can I submit the book to the Moderator?

No; only assessed work should be sent. Centres should avoid this practice because it adds to the cost of postage and makes unnecessary extra demands on Moderators.

17 Does **all** coursework have to be carried out under the direct supervision of the teacher?

*No; in order to meet the requirements of the descriptors, particularly for Skills **P** and **A**, candidates will need to carry out research which may require the use of library facilities, the Internet etc. Also, it may not be possible to devote sufficient time in the laboratory/classroom to allow candidates to write up their work. However, sufficient work must be completed under direct supervision to allow the teacher to authenticate the marks awarded, and this is left to the discretion of the Centre.*

18 How much help can I give students with their coursework?

This is a difficult question to answer. In general terms, direct help in the form of suggesting to a student how to carry out an investigation, or how to interpret the results, is unacceptable, while it is acceptable to draw the attention of the student to aspects of the assessment descriptors that he or she has not addressed.

In some circumstances it may be necessary to give direct help to students, for example to ensure that they are working safely or to get them through a difficulty. Such help should be taken into account in the award of marks and details must be provided to the moderator.

If students are to be given the opportunity to choose their own coursework tasks, guidance should be given by the teacher to ensure that that the tasks are of appropriate demand and likely to generate results capable of analysis. In a whole investigation, or if students are to be asked to carry out an investigation that they have planned, it is suggested that the draft plans are submitted to the teacher for an initial assessment to be made of the suitability of the strategy. Such assistance is acceptable without penalty provided that candidates are not given direct guidance about what to do.

19 Can I take in the work of my students, mark it, and then give it back to them for any errors to be corrected before taking it in again for a final mark to be awarded?

No; once the work has been handed in for marking, the marks awarded should stand. Assistance can be given to students while they are carrying out their work provided that it is limited to the identification of aspects of the assessment descriptors that have not been addressed. However, it is suggested that work for Skill ***P*** *should be collected in for an assessment of its suitability to be made before any practical work has been carried out, though Skill* ***P*** *should not be marked until the whole assessment has been completed.*

20 Can I use worksheets to set the tasks that my students are to carry out?

Yes; worksheets are very helpful, particularly if students are not being asked to plan the investigation themselves. However, a worksheet used to set a planning task which gives too much guidance as to the method to be used or the number of readings to be taken etc. may reduce the level of demand of the task and so limit the marks which can be awarded to candidates.

21 Where more than one skill is being assessed on a single piece of work, for example in a whole investigation, is it acceptable for the skills to be given widely differing marks?

If the level of demand of the task is limited, this will have an effect on all four skill areas. In this case, the marks awarded for Skill ***P*** *are likely to relate closely to the other skill areas since it is unlikely that a poor plan will generate a good set of data and that such data can be analysed or evaluated to generate high marks. However, a good plan may produce good results but the analysis and/or evaluation may be poor. Where marks do differ widely, they should be scrutinised carefully and if a teacher feels that widely differing marks can be justified, information must be provided to the moderator to support the marks awarded.*

22 Can work completed in the AS year be submitted for assessment for A2?

Yes; though the work submitted for AS must be set in the context of AS modules and work for A2 must be in the context of A2 modules. This means that candidates will need to draw on the knowledge and understanding of the appropriate modules in order to plan and/or analyse the experiment/investigation. However, there are some topics that relate to work in both AS and A2 but teachers should be aware of the need to provide tasks of appropriate demand for A2.

23 If Units 2833 or 2836 are re-taken, can the coursework marks be carried forward?

Yes; an entry for one of these units is for the written paper and the coursework component. Entry options for these units are provided for coursework marks to be carried forward, but it should be noted that marks for the written paper may ***not*** *be carried forward.*

7 Planning geological coursework

It is essential that Centres and candidates carefully plan and structure their work so that the essential elements associated with each skill can be addressed. The descriptions of the essential sub-skills of each skill outlined in Part 3 should be used together with the Mark Descriptors in Part 5, to plan coursework exercises. The production of worksheets with instructions closely related to these sub-skills will enhance the structuring of candidates' work and improve their chances of gaining a good mark. The use of sub-titles within candidates' work to show which skills (and sub-skills) are being dealt with, would also be welcome.

How many skills should be tested by any single exercise?

Technically, individual skills may be treated independently and assessed on different pieces of work, or they may be assessed together on the same piece of work, i.e. a single exercise can be used to cover 1, 2, 3 or all 4 skills. However, it is not recommended that Skills **P** or **E** be assessed on their own. It is expected that for Skill **P**, candidates' plans are put into action and produce data. Similarly, Skill **E** cannot be carried out effectively unless a plan, data from the implementing of the plan, and the results of analysis are available to evaluate. It is possible that some of this material could be provided by the teacher.

Generally, candidates cope quite well covering two skills on one exercise, provided they are issued with worksheets with instructions which relate to the required assessment criteria. If all four skills are to be tested it is essential that worksheets and instructions cover all the assessment criteria, and that it is clear to moderators, via titles, subtitles, teachers' comments, etc., which of these are being tested where.

The use of **Planning Tables** or **Matrices** should ensure that coursework exercises tackle assessment criteria. The examples that follow have been developed for an **Investigation into the Origin of Unconsolidated or Friable Sediments.** While a matrix has been suggested for each skill, this should not be taken as an indication that this exercise would give candidates equal opportunity to gain credit in all of them. Much would depend on the nature of the samples available (and field locations if used), the quality of the data collected and the precise instructions given to candidates.

Note that:

- while some exercises may be appropriate to both AS and A2, marks may **not** be submitted for both AS and A2 from the same piece of work;
- developing more than one exercise for assessment around the same basic technique should also be avoided, for example, if graphic logging is central to the work submitted for AS, then it not should form the basis of A2 work.

Investigation into the Origin of Unconsolidated or Friable Sediments

SKILL P: Planning

Sub-skill	Description	Related exercise objectives and opportunities
1	Identify and define a problem capable of investigation and explain its geological significance.	Investigating the likely process of transportation and depostional environment for a variety of unconsolidated sediments or friable sandstones. Explain the relationship between the process of transportation, depositional environment and physical properties of sediments such as grain size, sorting, skewness, clast shape, colour, etc.
2	Plan a fair test or practical procedure, identifying the equipment required and making predictions where appropriate.	Samples collected from the field, e.g. unconsolidated Pleistocene and Tertiary sediments; field apparatus might include tape, compass, clinometer, camera, trowel, small plastic bags & ties, labels, note book, ESTA card, etc. Lab apparatus: sieves, electronic balance, microscope, software.
3	Identify key factors to vary, control or take account of and select a suitable number and range of observations and/or measurements.	Key factors: grain/clast size, roundness, sphericity, composition, sorting, length of time the sieves are shaken. Five sediments to sample; decision to be made on amount of each to be sieved.
4	Use and evaluate information from a variety of sources to develop and justify an appropriate strategy.	Read appropriate class notes, texts and worksheets. Possible preliminary visit if samples are to be collected from the field. Define procedure for collecting and processing samples, recording and presenting the data.
5	Take into account the need for safe working and accurate and reliable data collection.	Standard field safety procedures; few safety issues in lab. Limitations of accuracy and reliability associated with sieving and sampling.
6	Use appropriate geological terminology and write up their plan ensuring correct spelling, punctuation and grammar.	Correct use of terminology associated with sediments, minerals, clast size & shape, texture, sedimentary structures, etc.

SKILL I: Implementing

Sub-skill	Description	Related exercise objectives and opportunities
1 to 4	Gather data safely, competently, accurately and systematically.	Correct, systematic and safe use of compass-clinometer, tapes, bags, labels, sieves, electronic balance, etc.
5 to 9	Record data clearly, accurately, systematically, with an appropriate level of detail and in an appropriate format.	Good opportunities for the use of tables, field note books, logs, labelled sketches and photographs, etc.

SKILL A: Analysing

Sub-skill	Description	Related exercise objectives and opportunities
1	Process and present data collected during investigations in an appropriate format.	Good opportunities for use of statistical and graphical techniques. Candidates using spreadsheets should note that an appropriate graphical technique is one which communicates effectively with the reader, not necessarily the most spectacular looking!
2	Use a variety of graphical and numerical techniques where appropriate.	Statistical techniques might include means, standard deviations, co-efficients of sorting and skewness, etc. Good graphical techniques might be labelled sketches, histograms, cumulative frequency curves, bivariate scattergrams, etc. Candidates should take care to annotate computer printouts with important points and explanations.
3	Use geological terminology correctly and write up work ensuring correct spelling, punctuation and grammar.	Correct use of terminology associated with sediments, minerals, clast size & shape, texture, sedimentary structures, etc.
4	Identify trends or patterns from the evidence collected and draw appropriate conclusions.	Ability to relate sediment characteristics (e.g. grain size, sorting, angularity, composition, sedimentary structures, fossil remains, etc.) to depositional environments and modes of transport.
5	Explain conclusions with reference to associated scientific knowledge and understanding.	Effective technical explanation of the nature of the sediments tested.

SKILL E: Evaluating

Sub-skill	Description	Related exercise objectives and opportunities
1	Recognise any anomalous results and suggest reasons for them.	An anomaly (in this case) can be taken as any characteristic which was not expected, e.g. a bimodal grain size distribution. There may not be any!
2	Assess the accuracy and reliability of the data.	Awareness that the samples could have been taken from unrepresentative areas.
3	Identify and assess the limitations of the techniques used and strategy followed and relate these to sources of error.	Account of the small errors in measurement using compass-clinometer, tape, balance, etc. Systematic errors implicit in sieving, e.g. not all the fines pass through the mesh; problems of standardising sieving times and degree of shaking.
4	Suggest and justify how the techniques used and strategy followed might be improved.	Reference to better methods of data collection in the field, extra samples, sieving for longer, using a machine to regulate the degree of shaking. Suggestion for different types of data which might be collected to help determine the provenance of the sediments.
5	Assess the significance of uncertainties in the evidence in terms of their effect on the final conclusions drawn.	An attempt to explore and evaluate a variety of possible interpretations of the characteristics of each sediment, in the light of the limitations in the techniques used and the data collected.

8 Suggested tasks for each module

The first column shows the skill/s best covered by the exercise described in the second column. The suggestions are not meant to be prescriptive (teachers may develop their own original ideas), nor do they necessarily involve equal levels of difficulty. Whatever work is chosen, teachers must ensure that coursework exercises are developed to a point where the full range of sub-skills associated with the specific skill/s being tested can be covered; otherwise, it will not be possible for candidates to achieve maximum marks. While certain skills may be suggested for each exercise, this should not be taken as meaning that the assessment of other skills is impossible; much will depend upon the nature of the exercises produced by centres. New approaches are always welcome.

The fact that an exercise is included in the suggestions should not be taken as an indication that it is necessarily safe. Potential hazards must be examined before proceeding in both laboratory and field.

AS Geology Coursework Suggestions

Ideas are listed below for each module of the AS specification, but Centres are free to design coursework exercises which relate to more than one module.

Module 2831: Global Tectonics and Geological Structures

Skill/s	**Coursework Ideas**
IAE	**FIELD:** Simple seismic refraction survey to plot the immediate sub-surface geology; also possible resistivity surveys.
IAE	**LAB:** Investigation of a specific earthquake, its effects and location; plotting of isoseismal lines from damage descriptions, locating epicentres and establishing the likely cause of the earthquake and any relationship between its effects, plate tectonics, surface geology and human development.
PIAE	**LAB:** Analysis of the location, severity and depth of earthquakes in relation to plate tectonic setting, for a given period, via the processing of data derived from the Internet.
PIAE	**LAB:** Comparison of gravity anomalies with maps of the solid geology; calculate the density of surface rocks from hand specimens and make suggestions on the nature of the sub-surface geology.
IA	**FIELD:** Identification and measurement of strike, true and apparent dips. Measuring and plotting dips of folded strata onto a stereonet.
PIAE	**FIELD:** Study of joint size, frequency, orientation and patterns in relation to rock type, folding and faulting. In some locations cleavage could also be analysed.
IA	**FIELD:** Identification, description and interpretation of geological structural, e.g. unconformities, folds, faults and their associated features.

PIAE	**LAB:** Simulation of deformation using different coloured plasticine in a squeeze box; simulate the deformation of ooliths; adjust temperature of plasticine and note the differences in deformation style.
PIA	**FIELD:** A study of the relationship between fold and fault types, locations and orientations.
PIAE	**FIELD:** Recognition and description of fold features ; identification of folds from outcrop patterns and simple field mapping.
PIA	**LAB or FIELD:** Study of an area where Caledonide rocks are in contact with younger strata; analysis of fold, fault and deformation styles and trends; use of geological maps may supplement field data.

Module 2832: The Rock Cycle - Processes and Products

Skill/s	**Coursework Ideas**
IA	**LAB or FIELD:** Recognition and description of the main rock groups from hand specimens, photomicrographs, drawings of thin sections, etc. N.B. A more fully developed exercise on the same theme could be attempted for Unit 2835, the Petrology Module.
PIAE	**LAB:** Experimental crystallisation using stearic acid, salol, alum, etc., adjusting temperatures to control cooling rates and observe the effects on crystal size and texture.
IA	**FIELD:** Identification and description of major and minor intrusions of discordant and concordant type and separation of lava flows and sills.
PIAE	**FIELD:** Analysis of weathering rates of tombstones in graveyards in relation to rock type (possibly using Rhan's Index); could be improved by comparing old urban areas which formerly suffered high SO2 levels with 'cleaner' rural areas.
PIAE	**LAB:** Simulated freeze-thaw using a variety of rock types - some friable and some not.
PIAE	**LAB:** Sieving exercise to determine depositional environment of unidentified sediments by establishing the relationship between sorting and skewness of grain size distributions, plus grain shape and roundness, grain composition, etc.
IAE	**LAB:** Experimental examination of the controls on saturation level for one salt by temperature and/or the presence of other salts in solution.
PAIE	**FIELD:** Study of the distribution, size, orientation and origin of sedimentary structures in modern depositional environments, e.g. beaches, estuaries & shallow rivers.
IA	**LAB:** Study of metamorphic textures in hand specimens and photographs of thin sections. N.B. A more fully developed exercise on the same theme could be attempted for Unit 2835, the Petrology module.
PIAE	**LAB:** Simulation of metamorphism using variable mixes of clay, silt and sand, firing in a kiln for varied periods and different temperatures; examine the degree of recrystallisation by testing the strength of the fired product.

PIAE	**LAB:** Analysis of the location, style, frequency and consequences of volcanic eruptions in relation to plate tectonic setting, for a given period, via the processing of data derived from the Internet.
IA	**LAB:** Analysis of a specific recent or historic volcanic eruption using secondary data, establishing the likely causes in relation to plate tectonic setting and discussing impacts on human development.
PIAE	**LAB:** Lava flow simulations using jelly, golden syrup, etc; varying temperatures, slope, composition (e.g. adding sand to increase viscosity).

Module 2833: Economic and Environmental geology

Skill/s	Coursework Ideas
IA	**FIELD:** A study of the location, composition, orientation, and morphology of mineral veins.
IAE	**LAB or FIELD:** Study of the arguments for and against an opencast mining application; visit a working opencast site & questionnaire survey on opinions of its social and economic consequences.
IAE	**LAB:** Experiments to determine the porosity and permeability of different sedimentary rocks with and explanation of the significance of the results for water, gas and oil reserves.
A	**LAB:** Practical exercise on dam and reservoir location in relation to geology and social and economic factors.
AIE	**LAB:** Testing the purity of limestones to assess their suitability for cement making.
A	**LAB:** Practical exercise on oil and gas accumulation using seismic and borehole data with information on the porosity & permeability of strata, potential source rocks, etc.
PIAE	**LAB:** Identification of suitable rocks for road stone or building stone, given specific requirements regarding durability, resistance to weathering, crystal size, etc.
PIAE	**FIELD:** Simple geophysical surveys, e.g. gravity survey across rocks of differing density, gravity or magnetic surveys across a basic dyke or iron ore deposit; etc.
PIAE	**LAB:** Geochemical analysis of stream water, sediments, etc.

A2 Geology Coursework Suggestions

Ideas are listed below for each module of the A2 specification, but Centres are free to design coursework exercises which relate to more than one module of the specification. Exercises can also cover modules studied in the AS specification, provided the emphasis is on material from A2.

Module 2834: Palaeontology

Skill/s	Coursework Ideas
PIAE	**LAB:** Experimental mechanical breakdown of shells of different types to establish their potential for survival as fossils in the littoral zone.
PIAE	**FIELD:** Study of a modern depositional environment, its life forms and their morphological adaptations with respect to mode of life; comparison with a similar ancient environment from the geological record.
IA	**FIELD or LAB:** Drawing, description and identification of fossils and analysis of fossil assemblages to interpret palaeoenvironment.
IA	**LAB or FIELD:** Study of the orientation and degree of preservation of fossils to assess palaeo-current strengths and directions.
PIAE	**LAB or FIELD:** Relative age dating of fossiliferous strata, e.g. to establish zone/s within the Jurassic; possible production of a stratigraphic column or a series of graphic logs for a small field area. Data from earlier visits could be used to supplement that collected by students.
IAE	**FIELD:** Construct the geological history for an area where a variety of relative dating techniques can be used.
IAE	**LAB or FIELD:** Investigation of Pleistocene and Holocene climatic change using unconsolidated sediments, fossil shell, pollen and insect analysis; comparison with present day distribution of the same species.

Module 2835: Petrology

N.B. Some of the exercises for Module 2832 may be developed for use in Module 2835.

Skill/s	**Coursework Ideas**
PIAE	**LAB:** Experimental crystallisation using stearic acid, salol or alum, at various temperatures to control cooling rates, observing the effects on crystal size and texture. Simulation of supercooling using Sodium Thiosulphate.
IAE	**LAB or FIELD:** Analysis of a basic igneous intrusion backed up by photomicrographs of thin sections of rock from different levels.
PIA	**LAB or FIELD:** Identification and description of various forms of igneous intrusion in the field perhaps with the aid of geological maps.
IA	**FIELD:** Study of hydrothermal, pegmatitic or aplitic veins in a granite and its aureole.
PIAE	**LAB:** Analysis of a specific recent or historic volcanic eruption using secondary data, establishing the likely causes in relation to plate tectonic setting and discussing impacts on human development.
PIAE	**FIELD:** A study of the changing textures, fossils and sedimentary structures in a modern depositional environment, e.g. a beach, estuary, river, etc.
IAE	**FIELD:** A study of sedimentary structures, textures and mineralogy relating to depositional environment, e.g. fabric analysis of till, palaeocurrent analysis of deltaic sediments, aeolian and flash flood deposits.
IA	**FIELD or LAB:** Identification, description and interpretation of sedimentary structures in clastic rocks in relation to present day processes operating on beaches, dunes, estuaries, shallow rivers, scree slopes, etc. A variety of possible laboratory simulations.
IA	**LAB or FIELD:** A study of the diachronous nature of certain lithostratigraphical divisions and unconformities, e.g. the base of the Carboniferous Limestone Series; field visits and inspection of stratigraphic columns from various locations could be used.
IA	**FIELD:** Investigation of lateral facies change, e.g. changes in grain size in Permo-Triassic flash flood deposits.
IAE	**FIELD:** Comparison of field successions to show similarities and changes of both lateral and vertical nature.
A	**LAB or FIELD:** Analysis of palaeowind directions in Permo-Triassic aeolian sandstones; comparison with today's prevailing winds in the British Isles.
IAE	**LAB:** Experimental examination of the controls on saturation level for one salt by temperature and/or the presence of other salts in solution; analysis of the composition of salts in solution in various present day salt lakes.
PIAE	**LAB:** Simulations of a turbidity currents, mechanical breakdown of fossils, precipitation of evaporites, etc.
PIAE	**LAB or FIELD:** Simulation of delta growth on the beach or using a flume.
IA	**LAB:** Analysis of geological maps; calculation and comparison of the thickness of certain strata (e.g. Jurassic) in different parts of Britain.

IA	**FIELD:** Study of the size, composition and orientation of phenocrysts in a granite intrusion.
PIAE	**LAB or FIELD:** Analysis of changing mineralogy and texture within the metamorphic aureole surrounding a plutonic intrusion. Field data may be supplemented with hand specimens and thin sections in the laboratory.
PIAE	**LAB or FIELD:** As above but using a regional metamorphic terrain.
PIAE	**LAB:** Investigation of the degree to which the depth of colour of igneous rocks is related to density and crystal size.
IA	**LAB:** A study of hand specimens and photomicrographs of thin sections.
IA	**FIELD:** Fieldwork in a variety of contrasting igneous terrains.
PIAE	**FIELD:** A study of the size and orientation of phenocrysts in a suitable outcrop of granite.
IA	**FIELD:** Identification, description and separation of lavas and sills.
IA	**FIELD:** A study and interpretation of sedimentary structures in sandstones, turbidites, conglomerates, etc. Many possible exercises.
PIAE	**FIELD:** A study of sedimentary structures in present day depositional environments and their relationship with processes; e.g. beaches, estuaries, shallow rivers, screes, etc.
PIAE	**LAB:** Simulations using wave tanks, flumes, etc.
PIAE	**LAB or FIELD:** Study of contrasting regional and contact metamorphic terrains. Field data may be supplemented with hand specimens and thin sections in the laboratory.

Synoptic fieldwork and mapwork exercises (these are permissible for A2)

AE	**LAB:** Construction of a scaled and detailed stratigraphic column for a geological map from which the published column has been removed and replaced by a simple key to the colours and code letters.
IAE	**LAB:** Calculate the true thickness of formations and other planar lithological units (using trigonometry) at various points on a geological map to produce an isopachyte / thickness contour map. Interpret the results.
IA	**LAB:** Structural analysis of a geological map to assess the size, style, trend and timing of folds, faults and unconformities.
IA	**LAB:** Practical exercise to assess the economic potential and problems of extraction of mineral resources from an area covered by a geological map.

9 Coursework forms

OCR is producing a Coursework Administration Pack for each specification containing coursework. This pack will contain copies of all relevant forms and instructions for completion.

10 OCR Contacts

Subject Officer for A Level Geology (subject-specific queries only)

OCR
1 Hills Road
Cambridge
CB1 2EU

Training and Customer Support (INSET enquiries)

OCR
Mill Wharf
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Birmingham
B6 4BU

Tel: 0121 628 2950
Fax: 0121 628 2940
Email: tcs@ocr.org.uk

OCR Information Bureau (other queries)

Tel: 01223 553998
Email: helpdesk@ocr.org.uk

Appendix 1

Exemplars

This section consists of exemplars of the suggested activities for Advanced Subsidiary (AS) and for Advanced level (A2) that are listed in the specification.

	AS Laboratory / Field Activities	**Skill P**	**Skill I**	**Skill A**	**Skill E**
1	An investigation into the geological structures of Fox Bay.		✓		
2	Analysing the causes and the effects of an earthquake.			✓	✓
3	Investigating the origin of five mystery sediments to determine the environment of deposition by sieving and sediment analysis.		✓	✓	
4	An investigation into the igneous structures of Arran.		✓	✓	
5	Porosity and permeability experiment.	✓			✓
6	Geophysical survey - a quarry investigation.	✓	✓		

	A2 Laboratory / Field Activities	**Skill P**	**Skill I**	**Skill A**	**Skill E**
7	Comparison of fossil assemblages and palaeoenvironments.			✓	✓
8	Mapping and graphic logging exercise		✓	✓	
9	A laboratory investigation into cooling rates and crystal size.	✓			✓
10	An investigation into the origin of Triassic sediments at Lochester	✓	✓		

Embedded within the exemplars is advice to Centres on the suitability of particular approaches to coursework. Two examples of candidates' work for the *Investigating the origin of five-mystery sediments* (Skills **I** & **A**) exercise have been included.

The Mark Descriptors listed earlier in this guide and in the specification in Appendix C can be used to give each of the exemplars a mark. The actual marks and comments about each piece of work provided by the Moderator are listed after each exemplar. Most of the exemplars include details of the exercises set and instructions given to candidates. For ease of reading, other than for some sketches and diagrams, originally hand-written work is presented in word-processed format.

N.B. The exemplars are included in this guide to give centres an idea of assessment standards. While some of them illustrate good practice, others show up some of the inappropriate approaches and conclusions that Centres and candidates often make. Do not assume that all the work included is of top standard.

Throughout the exemplar material, bulky primary data collected by candidates, and extended argument and analysis, have been omitted to save space. In its place there is a brief summary, *in italics*, of the approach used by the candidate.

Exemplar Investigation 1

An investigation into the geological structures of Fox Bay

The relevant sections of the module (2831) should be covered in class before this exercise is attempted. Candidates should also have had the opportunity to identify and analyse bedding planes, joints, faults, folds and unconformities via photographs or an introductory field trip. Basic field sketching techniques, graphical techniques (especially rose diagrams), use of compass, clinometer, tape, etc., should also have been taught.

An investigation into the geological structures of Fox Bay (Skills I and A)

(Based on Module 2831)

Instructions to candidates

Skill I: Implementing (Observing, describing, measuring, drawing)
Skill A: Analysing

Before you attempt this exercise you should familiarise yourself with the full details of Skills I and A by reading the sheets provided. Your written submission must clearly cover the sub-skills described.

Apparatus: clipboard, writing and drawing paper, pencils, compass, clinometer, tape, hand lens, geological hammer, camera, grain size & texture card.

Between the steps to the beach and the coastguard station there are two distinctly different sedimentary rock formations: a pale grey limestone and shale series, and a reddish brown series of sandstones and conglomerates.

- Starting from the steps and working south until you are below the coastguard station, whenever you consider that there has been any significant changes, record the: -

  (a) distance from the steps
  (b) angle and direction of dip of the strata
  (c) average distance between joints
  (d) azimuths of a selection of joints [Sub-skills I 2 to 9]

All readings should be taken from the lowermost 2 metres of the cliff face. [Sub-skill I 1]

- Stand back from the cliff section and make a fully labelled field sketch to show the geological structures present. [Sub-skills I 5 to 9]

- Identify and give supporting evidence for any folds present fully describing their location, style, trend, plunge, etc., using the appropriate terminology. [Sub-skills A 3, 4 & 5]

- Wherever you think you have found a fault, briefly outline the evidence for its existence and: -

  (a) state its locality [Sub-skills I 5 & 6]
  (b) measure and record its angle and direction of dip and the azimuth of its strike [Sub-skills I 2, 3, 5, 6]
  (c) assess the amount of movement and describe the direction of this movement [Sub-skills I 2, 3, 5, 6]
  (d) identify, giving reasons, the type of fault [Sub-skills A 4 & 5]
  (e) describe any other features associated with the fault and the strata in contact with it [Sub-skills I 2 to 9]

- Describe and explain the nature of the boundary between the grey limestones and the reddish brown sandstones and conglomerates. [Sub-skills I 5 to 9]

- Using appropriate graphical techniques explain how the frequency and pattern of jointing relates to: -

  (a) the different rock types present [Sub-skills A 1 to 5]
  (b) distance from faults and fold axes [Sub-skills A 1 to 5]

- Briefly describe the safety procedures followed during this field investigation. [Sub-skill I 1]

An investigation into the geological structures of Fox Bay

1. *The candidate recorded observations accurately, neatly and in detail in table format with columns for location, dips and joint directions. Several dip readings and compass bearings were taken at each location and a mean figure was calculated.*

2. Field sketch is on the next full page.

3. Of the two series of rocks examined only the grey limestones showed any evidence of folding. At the beginning of the section, at the foot of the steps the limestones are dipping north at about 30^{o} but 6 metres further south their dip is only 10^{o} and now to the west. Another 3 metres on and they are dipping at 43^{o} to the south. From this evidence I deduce that a fold axis runs through the point where the dip becomes 10^{o} W. This dip must be the plunge of the fold. Looking at the fold from further away it appears to be an open symmetrical anticline with an upright axis. I noticed that there were rather more joints near the hinge of this fold than on its limbs. Many of the joints ran parallel to the fold axis and some of had a white mineral in them.

   Thirteen metres south of the steps I found a syncline axis using the same basic techniques. This time I could not find a bedding plane good enough to measure the plunge. At 28 metres from the start is another anticline axis bounded to the north and south by faults, the southern one of which has apparently caused small scale drag folding and much jointing.

From a distance it is clear that that all these folds are upright and symmetrical. The beds do not alter in thickness in the axial regions so the folds must be concentric. All the folds trend east-west so the compression must have been from the north and south.

4. The first fault I found was 24 metres south of the steps. I recognised it because a particular band of fossiliferous limestone 20cm thick was suddenly displaced downwards to the south of a fracture that cut all the limestone beds but not the conglomerates.

   (a) The fault touches the beach 24 metres south of the steps

   (b) Its dip is 65° to the south and its strike is east-west

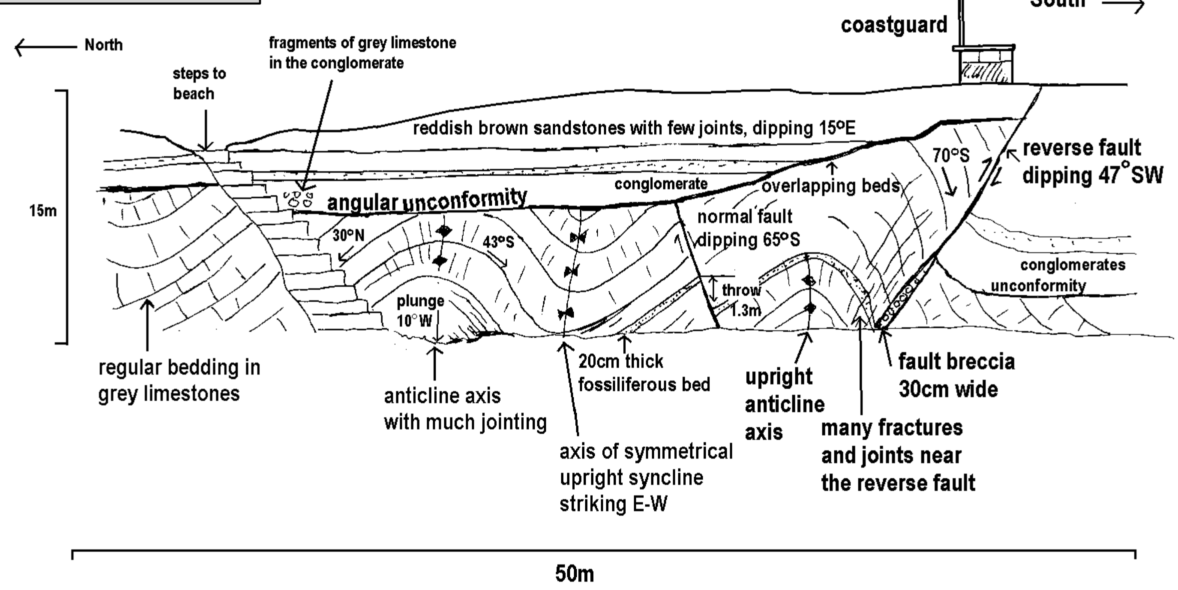
   (c) Looking closely at the fault I measured the throw at 1.3 metres to the south. There did not appear to be any evidence of strike slip.

   (d) This fault is a normal fault as the downthrow side forms the hanging wall

   (e) There were slickensides in evidence on the footwall. These were straight grooves running down parallel to the dip of the fault and must have been caused by dip-slip movement.

Teacher's Comment
Highly accurate field sketch; excellent presentation of data

A view of the geological structures of Fox Bay (SQ156039)
(from the west)



Another fault reaches the beach 30 metres south of the steps. This one was very easy to see as the unconformity which was near the cliff top on the northern side is suddenly only a metre above beach level on the south.

(a) 30 metres south of the steps

(b) Dip 47° to the north, striking east-west

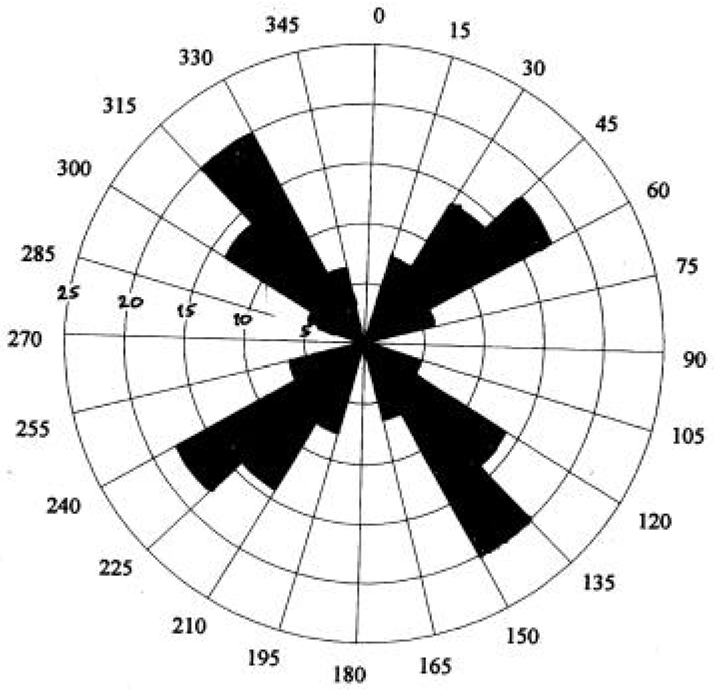
(c) Impossible to measure with a tape but about 5 metres to the south.

(d) This is a reverse fault as the fault dips towards the upthrow side.

(e) In the 2 metres above beach level there is a zone along the fault which is made up of broken angular blocks. The zone is around 30cm thick and the blocks vary from about 1 to 15cm. This material is a fault breccia. Another feature which was clearer from further away was that the conglomerates and sandstones on the southern side of the fault went from dipping 30° south at the fault contact to horizontal 2m further south. Elsewhere on this cliff section the sandstones and conglomerates are horizontal so this must be a drag fold. On the other side of the fault the limestones have a greater dip than normal and lots of joints. These features are also the result of frictional drag.

5. The boundary between the grey limestones and the conglomerates is an angular unconformity. The evidence for this is that the limestones are highly folded dipping north and south at around 45° but the overlying conglomerates and sandstones are almost horizontal (they actually dip 15° to the east but you cannot see this from the beach). The pressures which caused the folding must have occurred before the deposition of the overlying rocks. There must have been a period of uplift and erosion before these were laid down. The u/c surface is not horizontal and between 20 and 30 metres south of the steps the beds of conglomerate and sandstone are seen to overlap each other. Another bit of evidence that makes me think this is an unconformity is that near the steps I saw lumps of what appeared to be the grey limestone mixed in with the other stones forming the conglomerate. This suggests that the limestone was being eroded when the conglomerate was being laid down.

6(a) <u>A rose diagram to show the jointing pattern in the limestones</u>



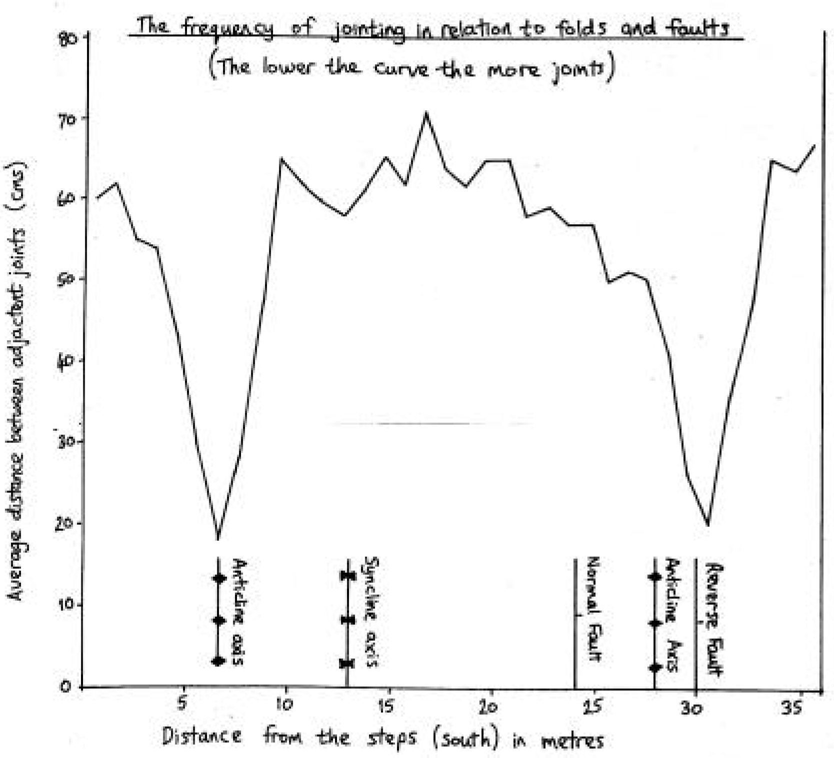
Candidate A showed the joint pattern for the reddish brown sandstones and conglomerates on tracing paper in overlay fashion so that it could be compared with that for the limestones.

From the two rose diagrams it is clear that the two rocks have very different joint patterns and frequencies. In the limestones the major joint sets have azimuths roughly NW-SE and NE-SW and a smaller set running E-W parallel with the fold axes. These latter joints appear to strongly relate to anticline axes and probably formed during folding because of tensional stresses.

Access to the conglomerates and sandstones was limited to the area near the steps, but even with this small sample it is clear that these rocks have far fewer joints than the limestones and only one major set which trends ESE-WNW.

6(b) From the graph (on the next page) it can be seen that there is an increase in jointing near to the northernmost anticline axis and close to the faults. Surprisingly, there does not seem to be an increase in joints at the syncline axis. The extra jointing at the northern anticline axis is parallel to the axis and has been caused by tensional stress during folding. The southern anticline has more joints on its southern limb than at the axis but this is probably because this limb is close to the reverse fault.

The normal fault does not seem to cause a big increase in joint numbers but the reverse fault does, but even in this latter case the increase is limited to strata within 2 metres of the fault plane. The extra joints close to the faults could have been caused by the rocks cracking up during the movement of the faults. This exercise was difficult because some of the beds of limestone had more joints than others regardless of folding and faulting; I therefore tried to pick similar beds when recording my joint data. The joints which increased near folds and faults tended to be those with an E-W azimuth.



7. Safety is a serious issue for this type of fieldwork. Some of the strata in the cliff are unstable so hard hats had to be worn while close to the cliff. Climbing the cliff was not allowed other than in areas where it was obviously safe. Firm footwear had to be worn. No use of the hammer was allowed on the cliff face or any other solid outcrops of rock. Geological hammers were allowed for loose material that had fallen to the base of the cliff, but we had to wear eye protection and ensure that other candidates were not too close. There was little risk the tide as escape from the beach was easy via the steps. The teacher carried a supply of basic first aid equipment and had a mobile phone on load from the school for the day of the trip.

Moderator's assessment of the Fox Bay exercise

The candidate made confident, competent and very accurate use of compass, clinometer and tape carefully checking her readings and taking extra measurements to ensure she collected a reliable and valid data set. She is clearly aware of the need for safety in the field. She clearly identified all fold axes, faults and unconformities and gave detailed descriptions with well argued supporting evidence. Assessment of fault movement is very accurate. Accurate and appropriate scale used for and marked on sketch. She identified and described all the 'subtle' structural features and showed excellent observational skills. Data of all forms is recorded accurately and systematically in an appropriate format. Excellent and inventive use of sketches, graphs and rose diagrams which were all well scaled and labelled. The correct geological terminology was used throughout and she shows excellent skills in processing data into tabular and graphical formats. Descriptions and explanations are all clear, relevant and logical. She identifies patterns in the data and carries out detailed processing, presenting the results using appropriate graphical (rose diagram & line graph) techniques. Advanced numerical techniques were not appropriate to this investigation. Her conclusions are well structured, comprehensive, concise, accurate and consistent with the processed data and clearly explained with reference to geological knowledge and understanding. She uses geological terminology correctly and her spelling punctuation and grammar are excellent.

The candidate clearly meets all the demands of Skills **I** and **A** to the highest level. (She has, in fact, done more than necessary to achieve top marks)

Skill **I**: Suggested mark: 7

Skill **A**: Suggested mark: 8

Advice to centres on using a field location (e.g. Fox Bay) for Skill P.

In fact, all four skills **could** have been tested at Fox Bay. **Whether most candidates can cope adequately with this approach, however, is doubtful. A poor plan may go on to result in major weaknesses in attempts to cover the other skills.**

However, Skills **P** and **E** could be tested if the original instruction sheet was not provided and the candidates were required to formulate their own plans to investigate the structures. In this case, written guidelines relating to planning would be essential for most candidates. Getting candidates to plan their own field investigation, however, may present some safety issues, so teachers should issue firm guidelines and should still be in position to supervise all candidates while they undertake their investigations.

Question: How can candidates create a plan to investigate a field location without a preliminary visit?

Answer: Teachers can give candidates basic uninterpreted information about a location before the visit. This may include any material which does not directly provide a plan, the data which they will be expected to collect, or any analysis or evaluation of that data. In the case of Fox Bay, the teacher may, for example:

- show them a general BGS map of the area.
- Give them a base map of the location.
- make available some data about the rock types they will be seeing.
- show a few slides or photographs of the area, but without any interpretative comment.
- provide a list of available equipment.
- state the length of time they will have to complete their investigation in the field.

Below is a list of instructions to enable candidates to attempt Skill **P** for Fox Bay. Other field locations could be treated in a similar manner.

Your task is to investigate the structural geology of Fox Bay. Read carefully the elements and descriptors of Skills **P**, **I**, **A** & **E** using the sheets provided before making your plan. You must have a complete plan before the visit to Fox Bay, but you can amend it when you get there, as circumstances require. In you plan you should:

1. Show evidence that you have analysed the information about Fox Bay which has been provided for you in school and considered how it might be used to help to develop the plan [Sub-skill **P** 4]
2. State clearly which aspects of structural geology you aim to investigate explain their geological significance. [Sub-skill **P** 1]
3. Identify the features and factors which you aim to measure, observe and record. [Sub-skill **P** 3]
4. Identify the equipment which you intend to use to fulfil this and explain the procedures you will adopt to ensure the accuracy and reliability of the data collected. [Sub-skill **P** 2 & 5]
5. Decide how many observation and measurements might be appropriate. [Sub-skill **P** 3]
6. Explain the measures which will need to be followed to ensure safety [Sub-skill **P** 5]
7. Produce a detailed itemised, sequential list of tasks and clearly justify the strategy and methods you are proposing [Sub-skills **P** 2 & 4]
8. Explain clearly how the information will be recorded, processed and analysed.
9. Include a section explaining how the processed data and the plan itself will be evaluated once the investigation is completed.
10. Use appropriate geological terminology and ensure that your spelling, punctuation and grammar are correct. [Sub-skill **P** 6]

A similar set of instructions could also be provided for Skills **I**, **A** and **E**.

Exemplar Investigation 2

Analysing the causes and effects of an earthquake

Analysing the causes and effects of earthquakes (Skills A and E)

(Based on Module 2831)

Instructions to candidates

Using a variety of secondary resources analyse the causes and effects of an earthquake. Your secondary resources may include textbooks, press reports, CD-Roms, the Internet, videos, etc. Following the structure set out below should help you to address the requirements of Skills A and E.

Causes and effects

You should:

1. Identify and describe the plate movements responsible.
2. Describe the severity using measurements of magnitude and intensity and explaining the effects of underlying geology and superficial deposits on the scale of the damage.
3. Describe the damage done to buildings, transport infrastructure, and the local/national economy and assess the death and injury toll and the damage to the fabric of human society. *Where numeric data is available you should attempt to process this statistically or present it in a graphical form which aids communication*.

Planning for the future

4. Assess the extent of the total damage caused by the earthquake in relation to the technological and economic development of the country concerned, outlining the extent to which technology and emergency relief and contingency plans limited its impact.
5. Describe any future measures that might be taken by the affected country to minimise earthquake risk and damage.

Evaluation

6 Evaluate the quality of your research methods and the data they generated, identifying the impacts of any limitations on data accuracy and the conclusions you were able to draw. You should also justify the techniques you used and explain how they could be improved under different circumstances.

Note: You must provide a full bibliography of the sources you used, including World Wide Web addresses (URLs). Plagiarism (i.e. direct copying of text or diagrams, without acknowledgement) will not be tolerated.

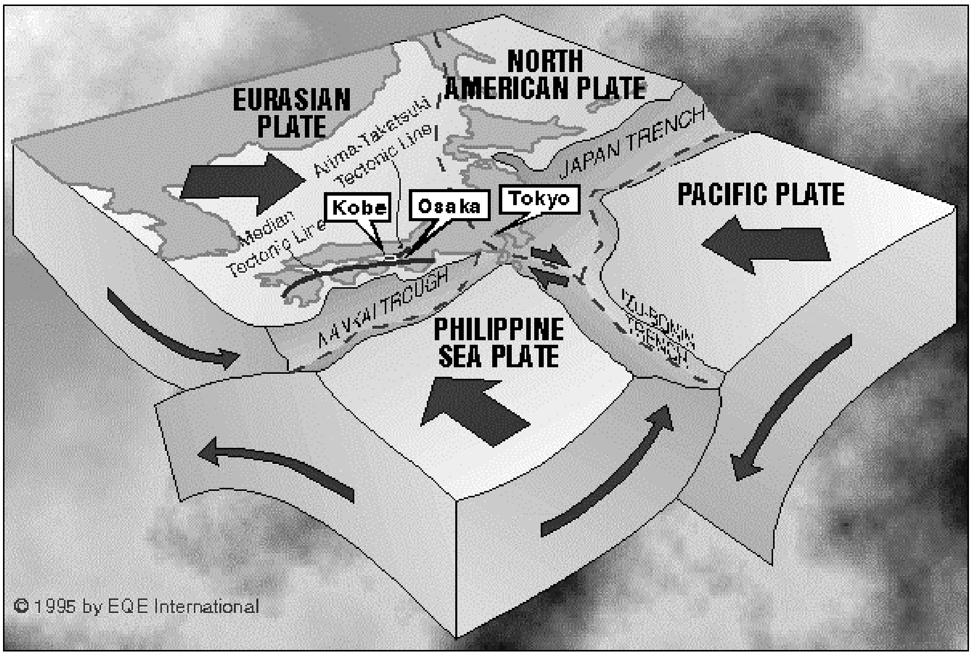
An analysis of the causes and effects of the Kobe earthquake of 17th January 1995

N.B. OCR gratefully acknowledges the assistance of EQE International in giving permission to include several of the images in this report.

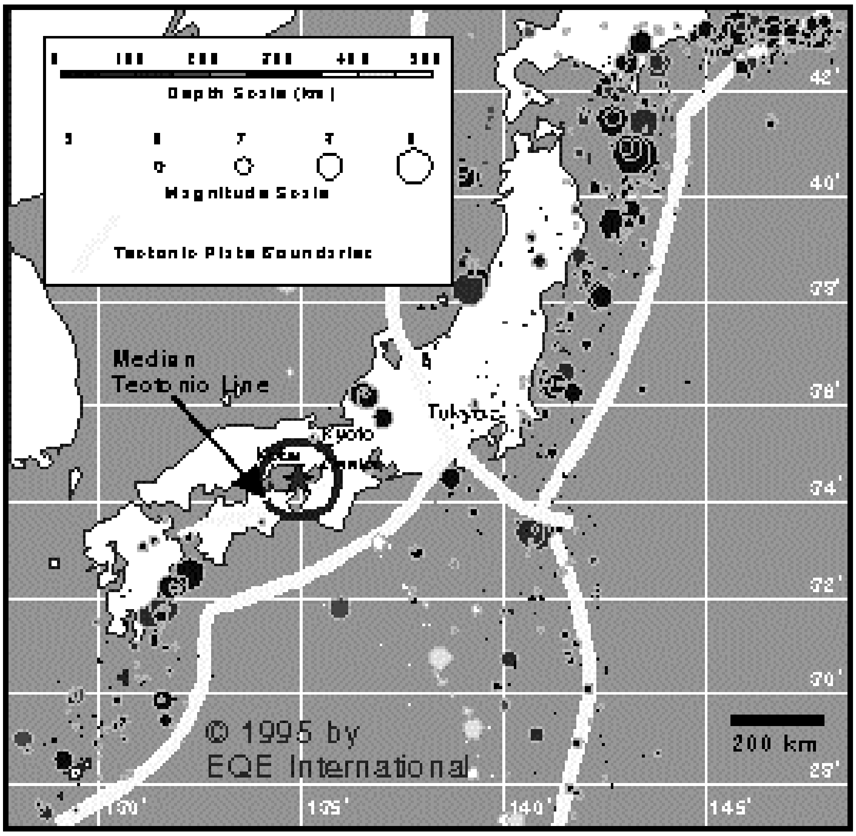
CAUSES AND EFFECTS

1. Plate tectonic origins of the Kobe earthquake

This earthquake occurred at 5:46 a.m., lasted 20 seconds, had a magnitude 7.2 and struck Japan's second-most populated area (after Tokyo) which has around 10 million people. The focus was shallow (15 to 20km) and on a fault running from Awaji Island through Kobe. SW Japan is located on the SE margin of the Eurasian Plate, where the Philippine Sea Plate is being subducted beneath the Eurasian Plate in a NW direction along the Nankai Trough. Part of the plate movement is along a dextral wrench fault known as the Median Tectonic Line which lies immediately south of the area. The focus was on a smaller dextral fault branching NW from this, called the Arima-Takatsuki Tectonic Line. The earthquake was unexpected because this area has shown little seismicity in recent historical time. The plate tectonic situation surrounding the Kobe earthquake is shown in the diagram below.



As can be seen from the diagram, the plate tectonic situation affecting Japan is very complex with four main plates being involved. With a simple subduction zone you might expect to get just reverse faults, thrusts and a few normal faults where mountains are being uplifted. In this case, however, there is also quite a lot of lateral movement which produces the wrench faults which affect southern Japan.



The map shows the location magnitude and depth of earthquakes in the Japanese area in recent years.

You can see that the area around Kobe does not seem to be very active.

This explains why the earthquake was a shock.

An approximately 9-kilometer-long surface fault rupture was identified along the Nojima Fault, which is on the NW coast of Awaji Island, SW of Kobe. The dextral fault strikes NW-SE, dips steeply to the southeast. Vertical displacements were 1.2 to 1.5 metres, and right-lateral displacements were 1.5 to 2.0 metres. Movements in the past have produced a 6 to 7 metre high fault scarp. Research shows that the long-term slip rate for the fault is around 1mm per year and that the return period of such an earthquake would be once every 1,000 to 1,500 years.

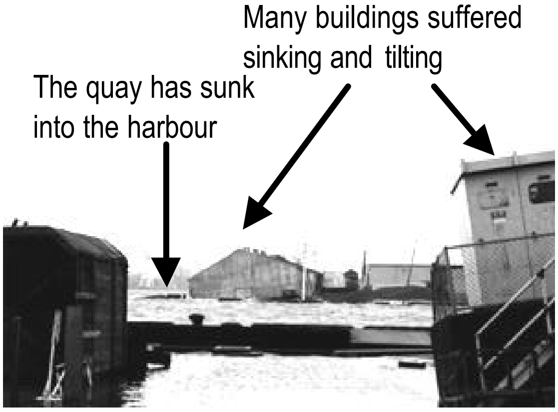
The intensity of the earthquake reached points 10 to 11 on the Modified Mercalli Intensity scale. The maximum horizontal accelerations seem to have reached about 981 cm/sec/sec (very similar to the Northridge earthquake) and these extended NE from the epicentre producing an eliptical pattern of isoseismal lines.

The candidate included a chloropleth and isoline maps showing the differences in ground movements copied from the web, but did add his own labels for explanation.

2. The impact of superficial deposits on the Kobe earthquake magnitude and intensity

Surface deposits have no influence on Richter magnitude of earthquakes (7.2 in this one) but they can control the amount of surface movement and damage, thereby affecting the Mercalli intensity. In this area, granites are overlain alluvium and inter-bedded marine clays, followed by further alluvium. Due to the lack of flat land for building the Japanese used fill material (waste, building rubble, etc) to extend the waterfront and create human-made islands for port and industrial development. Both the naturally occurring alluvium and the fill deposits were very prone to liquefaction which caused the collapse of buildings, underground infrastructure, the port, highways, etc. Many buildings just sunk into the waterlogged material produced by the quake.

Part of the Port of Kobe



Liquefaction happens when shock wave cause loosely packed grains to become better packed. This causes a reduction in pore space and any water is expelled upward causing water logging of surface deposits, which makes the foundations of buildings unstable.

The worst affected areas covered many square kilometres and were on the coast, near watercourses and especially on reclaimed land, where wet sand was ejected through the fill and the land fell up to 3 metres. Even parts of the city centre near the harbour were affected. This settlement of land caused severe damage to underground services (gas, water, sewage) which took months to repair.

Dozens of kilometres of seawalls along the port were affected by lateral spreading (up to 4m) vertical settlement of 2 to 3 meters associated with liquefaction. Newer, engineered fills performed better than the old ones but were still inadequate.

The candidate included a further labelled photograph showing large areas where sand and mud had been ejected from the ground.

Older, heavy concrete, industrial buildings, on mat foundations suffered worst from liquefaction. Buildings, even of multi-storey type, supported on piles, survived quite well. Often the paths around these settled 50 cm or more, but buildings retained their position. The same was generally true for newer highway structures supported on piles, except where these were of split-level.

3. Kobe Damage Report

Damage extended up to 100km from the epicentre.

Damage to buildings

Japanese building standards were revised in 1981 and it is notable that concrete frame buildings constructed before this date suffered the worst damage. Later steel-framed buildings with concrete shear walls suffered the least damage.

High-rise buildings suffered serious damage, even if steel framed, and would almost certainly have collapsed if the earthquake had gone on for longer.

In California earthquake-related building regulations are stricter for public buildings such as schools and hospitals. Builders can follow the more demanding regulations for other structures if they wish.

Over 150 fires occurred after the earthquake and fallen buildings and burst water mains stopped the fire fighters from getting to many of them. However, calm wind conditions prevented conflagrations. The biggest peacetime fires this century have occurred in the USA and Japan following earthquakes and it is clear that fire must be recognised by planners as a major earthquake related hazard.

Buildings

Over 100,000 buildings very destroyed and a further 80,000 buildings were badly damaged. Many of these were traditional-style Japanese residences and small, traditional commercial buildings of three stories or less. Mid-rise buildings, between 6 to 12 stories, in Kobe's CBD, suffered severe damage with many collapsing toward the north, but many newer structures performed quite well and withstood the earthquake with little or no damage. In the CBD 60% of buildings were heavily damaged and about 20% completely or partially collapsed. About 50% of the multifamily dwellings in Kobe were destroyed or had to be demolished, making over 300,000 people homeless.

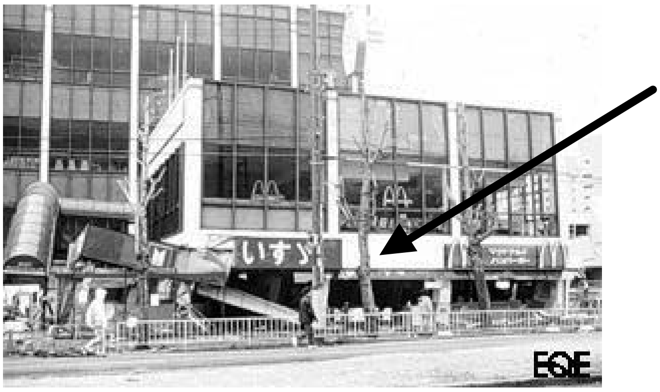
A survey of commercial buildings being demolished in the central Kobe two months after the earthquake found that damage was strongly related to architecture, as shown below.

Building Type	Percentage of the total needing demolition
Frame	70%
Shear Wall	20%

After the devastating 1923 Tokyo earthquake Japan introduced building codes which have been tightened up and improved over the years and are as advanced as any in the world. In recent years American and Japanese professionals have working together on seismic research and building design. Present Japanese standards plan for buildings to suffer no damage from small to medium sized quakes and to avoid collapse during big quakes. The bigger the building the greater the earthquake resistant design regulations. American rules are less stringent.

In general, the Japanese policy worked for the Kobe quake but some newer buildings, including high rises, were still severely damaged. Structures that did poorly included older houses and smaller commercial buildings (both concrete and steel), and mid-rise concrete structures designed and constructed prior to the early 1980s.

Mid rise (6 to 12 storeys) non-ductile reinforced concrete **frame buildings** often suffered the collapse of one or more floors, usually within the middle third of the building height. This may have been due to ground movements being in harmony with higher vibration modes for these buildings, resulting in increased stresses. It could also be due to changes in building strength with height. The pre-1981 code only required that a concrete-frame building only the lowest 6 storeys needed to be steel reinforced. This resulted in weaker upper storeys. Failure of the ground floor was also common and may be due to weaker structure caused by the presence of garages or shop fronts with large windows. Hundreds of thousands of these buildings exist in seismically active areas throughout the world. Unless these buildings are retrofitted, many lives will be needlessly lost in future major earthquakes.



This picture shows the collapse of the ground floor of Macdonald's in Kobe. It is an example of soft storey collapse, caused by structurally weaker ground floor design used to accommodate larger windows for display purposes and a wide seating area for the café.

Although more resistant, many reinforced concrete **shear wall buildings** were also severely damaged, and some had partial collapses. Many of these were blocks of flats where the shear walls had severe cracks and horizontal displacements at construction joints offsetting one floor from the next.

The candidate grouped several coloured images from the Internet to make a collage which was labelled to show the damage and building types.

Many severely damaged shear wall buildings (even new ones) had been designed to cater for different uses at different levels, resulting in weakness in the structure.

Braced frame-wall or reinforced concrete-encased steel-frame buildings, did rather better, but surprisingly **steel-frame buildings** without concrete, which one would expect to absorb seismic stresses, sometimes faired poorly with some collapses due to poor engineering. The steel frames suffered from twisting and deformation but often other elements (including windows) of the buildings did not suffer much damage. More recently built steel framed high-rise structures withstood the earthquake with little damage.

Traditional Japanese **wood-frame buildings** normally have very heavy mud and tile roofs (to prevent typhoon damage), supported by post-and-beam construction weakly set in a foundations are often stone or concrete blocks. These suffered the most serious damage in Kobe and were responsible for most casualties. Collapses led to the rupture of many gas lines. Many of the older homes, were weakened by wood rot. The damage was reminiscent of that in the Marina District after the 1989 Loma Prieta (San Francisco Bay Area) Earthquake.

Kobe has few **unreinforced masonry buildings** but those that existed suffered extensive damage to the masonry walls and partial collapse of floor and roof systems.

Base Isolation is the name given to a technique that reduces the damage and vibration of a structure subjected to earthquake motions by isolating the building from the ground motion through the use of mechanical bearings. These bearings are designed to limit forces transferred from the foundation to the building. The only base-isolated structure in the Kobe area was located a 32km from the epicentre. However, it suffered no damage and the system appeared to work well. The peak acceleration on the roof of the six-story isolated structure was reported to be only one-third of that at ground level.

While most building damage was due to seismic waves directly a significant amount was caused by the **fire** which followed. Fire risks are very high in Japan because of:

- high population densities
- very narrow streets and alleys which cannot act as fire breaks
- numerous old wood-frame smaller commercial and residential buildings mixed in the commercial zones of towns
- unanchored or unprotected gas storage tanks or heaters
- a mix of collapse-prone old buildings in all built-up areas.

Although Kobe had specially designed underground water cisterns to fight fire in the event of an earthquake and loss of normal water supply lines, the severity of the quake and the collapsed buildings meant they proved ineffective. The fire service was of a high standard and had a civil disaster contingency plan plus a volunteer fire corps with about 4,000 members. Despite all of this the loss of water supply was catastrophic and fire raged for over 36 hours unchecked, with water eventually having to be pumped out of the harbour. Within minutes of the quake over 100 fires broke out primarily in densely built-up, low-rise areas of the central city, which comprise mixed residential-commercial occupancies, predominantly of wood construction. Within 1 to 2 hours, several large conflagrations had developed. Roads were blocked by fallen masonry and abandoned vehicles and vehicles with people trying to leave the area or trace relatives.

Luckily the wind was calm, and fire advance was slow and often stopped by narrow firebreaks. However, the final burned area in Kobe was estimated at 1 million square metres.

Damage to transport

Blocked street in central Kobe

The earthquake caused massive damage to the transport system. Kobe lies on the main transport corridor between the central and SW Honshu. The corridor is less than 5km in this area because of the mountains inland. Major national roads, bridges, and rail systems were damaged and traffic was forced to re-route through Kobe itself causing massive congestion, which greatly impeded relief efforts. Many streets were unpassable due to debris from collapsed buildings and ground movement. The death toll could have been much higher if the quake had occurred in the rush hour.

Roads & bridges: The Hanshin Expressway is the main road through the Kobe-Osaka corridor and was built in the mid- to late 1960s. It is elevated for more than 40km, and supported by single, large reinforced concrete piers spaced every 32m many of which collapsed. Single column cantilever design was chosen to conserve valuable space in an overcrowded country. Older highways in the USA are of similar design but since the 1989 Loma Prieta earthquake many have been retrofitted with steel jackets to prevent collapse. Those that did collapse in the 1994 Northridge earthquake had not yet been retrofitted, neither had the Kobe-Osaka highway because the area was not considered high risk. The Japanese columns used to support the elevated roads are much larger than those in the USA and require 50% more steel. The assumption that they would be stronger proved wrong, as they were too rigid and fractured more easily than thinner more ductile structures. Another newer elevated highway (the Wangan Expressway) also suffered severe damage, despite the latest earthquake resistant technology. Although the columns did not shear, the area, being underlain be weak natural soils and landfill, suffered severe liquefaction, with up to 1.5m subsidence and much lateral spreading, which also accounted for the collapse of the approach to a new arch bridge and the total collapse of an older one. The damage to the newer bridge sadly indicates that the latest design criteria and practices, at least in areas of soft soils, are inadequate. As this was the first major earthquake to test a modern bridge a re-evaluation of design criteria may be needed worldwide.

Railways: A with the highways, elevated railways and stations were very badly damaged with embankment failures, overpass collapses and distorted rails. Some carriages fell onto city streets and the Rokkomichi Station (built in 1972) using reinforced concrete was totally destroyed and a viaduct carrying the bullet train was severely damaged with columns shearing and some spans collapsing. Fortunately, the earthquake occurred before the train service from Kobe commenced for the day. Commuter journeys between Osaka and Kobe took 2 hours in the months after the quake, the normal being 30 minutes. Delays will also add to transport costs for industry. Earthquakes rarely damage **underground railway systems**, but this one was severe enough to cause the collapse of some tunnels, which took 6 months to repair.

Airports: Neither of the two airports serving the area suffered much damage despite Kansai International Airport (completed 1994) being built on a human-made island. Both, however, were outside the zone of severe ground motion.

Ports: Kobe had one of the largest container ports accounting for 30% of Japan's container trade, but it was almost totally destroyed by the earthquake with damage exceeding £6 billion. The port was built on 3 man-made islands and included 27 active container berths and various other wharves, ferry terminals, roll-on facilities, and warehousing, plus numerous other facilities, including an extensive shipyard. Also, at the time of the earthquake, several new islands were under development. Most of the damage resulted from liquefaction and lateral spreading. Quay walls rotated and slid outward and subsidence of up to 3m occurred behind them flooding warehouses. With large quantities of sand ejected. Most of the cranes were severely damaged. Kobe's container trade has gone to other nearby ports such as Osaka, Nagoya, and Yokohama. The economic loss to the local area from the loss of the port has been devastating. The damage happened despite the fact that the islands and quays had been designed to the highest specification matching or exceeding that of the USA. It is clear that design standards will have to be re-evaluated. Kobe's port may never be fully rebuilt.

Damage to services

Electric Power: Fortunately, the epicentre was located in one of the few areas which would not significantly affect the transmission system and also missed a cluster of fossil fuel plants to the SE and nuclear power plants over 100km to the north. Only 10 of the areas 63 fossil fuel plants was damaged and none of the 141 hydroelectric plants. Several substations, a few fossil plants and a gas turbine plant, however, were damaged cutting power to over 1 million users for a few hours after the quake. A massive repair effort by the Kansai Electric Company restored all power within a few days. Where damage did occur it was mostly the result of ground settlement during liquefaction.

Telecommunications: The system suffered little damage away from the epicentral area, where a week after the event 25,000 telephone lines were still disconnected. More than 2,000 telephones were installed for public use at shelters and public offices.

Water: The reservoir system was designed to be operable after earthquakes. Of the 30 reservoirs serving the area, 22 had automatic emergency shutdown valves and multiple storage tanks. All 22 valves tripped and worked correctly saving 30,000 cubic meters of water (8 million gallons). Movements associated with liquefaction, however, caused over 2,000 breaks to pipelines which disrupted supply to most of the area. Tanks without automatic shutoff valves drained within 8 hours of the earthquake leaving an acute water shortage for fighting the fires. With water mains destroyed, the reserve water from the reservoirs fitted with automatic shutdown was also unavailable for fire fighting. Nine days after the earthquake, 367,000 households in Kobe still had their water supply cut and the restoration to the worst affected areas took 2 months. Emergency distribution of water was by very restricted with many citizens having to use buckets and tubs. Few tank trucks were available but near the harbour small ships were used to bring in and distribute fresh water. Sewerage systems suffered similar damage to the water mains, but did not overflow as flushing was impossible. Public toilets, however, did overflowed, and sanitation was a problem.

Gas: The system had at least 1,400 breaks to underground pipes a supply was disrupted to 834,000 households. Japanese buildings and homes have automatic gas shutoff systems, but many failed to work because of building collapses, other building damage, and broken pipes. Repair of the gas mains took over 2 months.

Economic damage and impact on Industrial Facilities

Between 3% and 5% of Japan's industry was located in the area of severe damage, including everything from light manufacturing to high technology and heavy industry, most of which was concentrated near the port on landfill or very recent, soft soils. Damage due to liquefaction was severe and the reduced ability to transport raw materials and finished goods to, from, and within the region will also greatly impact industry in the Kobe area. Industries affected include shipbuilding, steel plants, breweries, pharmaceutical firms, computer component manufacturing plants, and consumer goods production facilities.

The most severe damage was to areas near the port, especially the man-made islands. Inland, large industrial buildings survived better than housing, elevated roads, etc. Steel manufacturers were badly hit with one company likely to go close its Kobe plant and concentrate production elsewhere. Structural, fire, or contents damage affected more than 40% of the local knitted goods manufacturers and more than 90% of the synthetic leather shoe manufacturing facilities. City officials worry that production will now be moved to low-wage countries like China. Heavy damage to the numerous liquor (sake) production facilities also occurred, hitting national supplies (one-third of the country's liquor production took place in Kobe). Shipbuilding and chemical works were also badly hit.

A great deal of non-structural damage was also caused to industry with tilting and movement causing damage and misalignment of equipment which will cost time and money to put right before production can resume. Leakage of fire sprinkler lines caused extensive damage to goods, stock, and machinery. Major damage was done to unanchored equipment such as computers and office furniture. Much could have been avoided using simple anchorage methods.

Japanese businesses do not usually store large numbers of parts, relying on just-in-time delivery. The earthquake resulted in severe shortages of components manufactured in Kobe and thereby caused interrupted production in other parts of the country. There are also no insurance companies which cover disruption of this type.

The damage to the workforce resulting in death, injury and trauma and the loss of housing and mass transit systems meant that many employees were unable to work for some time after the earthquake. Many businesses went bankrupt as a result.

Many retail and service businesses were unable to start up again for several weeks after the earthquake.

On the day of the quake the Nikkei Index dropped by 5.6% and the total repair cost may exceed £100 billion for structural damage alone (excluding the internal contents of buildings), many times worse than that of the Northridge quake. The losses due to business failure and interruption to import and export trade may even exceed this. The whole of Japan will have to contribute to the recovery of the Kobe area from tax revenue and raising taxes could further damage the country's economic health. In fact, the Japanese economy suffered one of its worst recessions since the war in the years after the earthquake, which contributed to economic strife through the western Pacific basin.

The only companies to benefit from the earthquake are those involved in the reconstruction effort.

Unlike the USA, where earthquakes produce massive claims against insurance companies, in Japan the earthquake threat is too widespread and severe to make it insurable by private companies and the government sponsored scheme only covers between 30 and 50% of replacement value. Only 3% of homeowners even had this basic insurance, while in California about 40% are fully covered

Damage to human society, deaths and injuries

With around 5,500 people dead, 35,000 injured, almost 180,000 buildings destroyed and 300,000 homeless, the Kobe earthquake has inflicted the most serious damage on an economically developed country in recent decades., but seems modest compared to the 1923 Great Kanto Earthquake, when about 140,000 people were killed. The economic loss from the Kobe quake, however, is probably the largest ever caused by a natural disaster.

Kobe suffered greater damage and more deaths and casualties than Northridge because of its extremely dense population, older building stock and its liquefaction prone soils.

For the homeless, there were the hardships of finding shelter; securing food and water; locating friends and family members; and acquiring warm clothing for the cold, damp winter weather. Although many people were taken in by friends and relatives and some could afford hotels over 235,000 required emergency shelter and many camped in public parks or assembled makeshift shelters from materials salvaged from the wreckage of their homes. Temporary shelters included community centres, schools, and other public buildings, many of which lacked adequate facilities, causing sanitation problems and increased risk of disease. Two weeks after the earthquake influenza and pneumonia became common. In the early days, food, water, sanitation, blankets and warm clothing were all in short supply. Thereafter help from government agencies, volunteer organisations and local companies eased the situation dramatically.

As with most disasters, the poor and the elderly suffered the most, being unable for financial or physical reasons to make rapid recovery from the event.

PLANNING FOR THE FUTURE

4. How ready was Kobe for the earthquake?

The Kobe Earthquake clearly shows the damage that can be expected in modern industrialised countries. Much of the damage could have been predicted and much prevented by putting into action existing earthquake resistant technology. The Kobe area, however, was not thought to be at great risk so, although some measures had been taken, there was a lack of preparedness for the event. As a result much of the infrastructure and building stock of a modern city was destroyed. Many other areas are equally at risk of falling into a false sense of security, e.g. all of California and most of the west coast of the USA are at risk of a similar event, but have had nothing on this scale in recent (or even historical) times. Such places, need to look at the evidence in favour of the **seismic gap theory**, which suggests that it is the very places which have not had major quakes that are most likely to get them in the future, as seismic stresses have not been relieved.

While the earthquake was unusually severe the preparedness and emergency response efforts in Kobe were less than satisfactory. The immediate urban search and rescue effort was inadequate for the thousands of buildings destroyed in this event. The problem would have been further compounded had the earthquake occurred during the day, when thousands more people would have been trapped in major derailments and office building collapses.

Preparedness and emergency response are often the most affordable, if not the only possible, mitigation techniques available to many regions. No matter what structural retrofitting may precede an event, it can never entirely mitigate the problem, so that a large, prepared emergency response capability will always be required.

Surprisingly little of the Kobe event provided new lessons in earthquake hazard management. Most of the causes damage had been repeatedly observed in the past, e.g. the collapse of elevated highways. However, this was the first large earthquake to test many new hazard resistant designs. Many new buildings and other structures, built to the most recent design codes, performed very well, while a few failed dramatically, even though they were expected do well. Because of this, we now know a little bit more about what works and what does not.

The candidate then went on to discuss the potential for similar damage to occur in other cities in the economically developed world and assess their preparedness.

5. Future earthquake hazard management measures

The Kobe Earthquake dramatically illustrates the damage that can be expected from earthquakes to modern industrialized society. Most of what happened could have been predicted and much of the damage was preventable. Hopefully, the disaster will spur designers and building owners to continue, and to increase where needed, their efforts to improve the earthquake resistance of their properties. From the evidence studied it is possible to make a series of recommendations about managing the earthquake threat in the future:

Building Performance

- Enforce higher design specifications for new buildings
- Buildings with reinforced concrete shear walls did the best so all new buildings should include shear walls as standard.
- Older non-ductile concrete buildings did worst and no further construction of these should be allowed.
- Large newer commercial and industrial steel-frame buildings performed better than any other type, but some more radical new steel frame buildings suffered serious damage. These designs were often aimed at achieving the same strength with reduced steel and lower costs. Caution must be exercised with all new designs.
- Owners often have unrealistic ideas about how earthquake proof their buildings are. Even the best designs only aim to prevent the building from total collapse in the event of a large earthquake, thus reducing deaths and injuries. Owners and occupants still need to be aware of the risks and enforce adequate earthquake drills.
- Even with the best of designs, building on soft silty soils, alluvium and landfill sites with high water tables should be avoided if at al possible due to the potential effects of liquefaction. In a country like Japan, however, it is difficult to see how building on such area can be avoided.
- The use of piles, extending through loose material into solid rock did much to reduce the impacts of liquefaction, and should be enforced in prone areas.

Bridges and Expressways

- All elevated roadways should have their columns built or retrofitted with steel jackets.
- Supporting cantilever columns may needed to be more closely packed and have broader supports to carry roadways where liquefaction causes spreading.
- The performance of Kobe's new bridges is being studied in depth, as this is by far the strongest earthquake to affect such new designs. Improvements should follow and older bridges should be retrofitted to new standards.

Gas

- Further efforts are required by suppliers are needed to find high-technology methods for seismically sensitive automatic system control at the meter and upstream, to conserve supplies and prevent fire.

Electricity

- Although the system coped fairly well, most of its most vulnerable parts were distant from the epicentre. Efforts are required to review electric systems in seismic areas for potential damage and emergency preparedness, and to investigate methods for reducing damage.

Water

- Despite the existence of shutoff valves, the lack of water contributed to the fire problem. Three main problems remain to be solved:
    1. Further shutoff valves are needed at key locations in the distribution system and they need to be remotely operable.
    2. The capacity of cisterns, holding emergency water for fire fighting, needs to be vastly increased.
    3. Greater co-ordination between the fire and water supply agencies is needed.

Fire

- More research is needed into the post earthquake fire risk with increased training of citizen fire brigades, alternative water supplies, and smart meter control of gas and water systems. There may also need to be further planning regulations on minimum street widths, building materials, etc. to avoid the spread of fires.

EVALUATION

Most of the research for this investigation was carried out using the Internet. One of the major problems was the vast amount of information that was available. It was difficult to decide which sites to use and which to leave alone. Deciding which data to use was also a problem. As a source of data, the Internet exceeded anything I could find in newspaper cuttings in the College library or in textbooks (most of them were written before the earthquake). There are, however, some obvious drawbacks and limitations associated with using the Web (or other secondary sources):

It is almost impossible to establish the accuracy of the data, as direct observation is impossible. In this case every effort was made to cross check data using different sites. Even then the different web sites have probably got their information from the same source, probably journalist reports and post earthquake damage investigations. How can such data be systematically recorded and quantified?

Whenever, journalist make a report, they will select the things that they think matter or that they believe their readership wants to hear. They are, therefore, very selective and may miss out aspects which are quite important for a proper scientific analysis. Also, in a situation like an earthquake, communications are badly damaged and collecting information may be very difficult, so there are likely to be serious omissions.

However, some of web sites used were compiled well after the event and based on a much more comprehensive set of data. One of them was produced for civil engineers and assessed precise ground movements and the impacts that these had on structures, so there was some very accurate data available.

Although it is possible to plot the focus of the earthquake, it is difficult to tell what exactly happened due to its depth beneath the surface. The movements at the surface are merely a reflection of this.

The report could be improved by adopting a more systematic approach to the study and collecting more numerical data which could be mapped. This, however, would take far too much time for me and the data would be difficult to come by.

The scale of the disaster and the complexity of its impacts make it very difficult to be certain about the total impact on the Japanese economy and that of its trading partners in the West Pacific region.

If I could gain access to the data, I would like to study the precise level of damage in relation to superficial deposits and the fault patterns in the underlying basement rocks. This would help to explain why, even accounting for liquefaction in poorly compacted sediments, there was such a variation in damage levels and also the elliptical pattern of the isoseismal lines.

Bibliography: *The candidate supplied a full list of web sites, CD-Roms and other secondary sources used.*

Moderator's assessment of the earthquake exercise

There is always a danger with Internet based research that candidates will simply **copy** large areas of text and pictures into their reports without much attempt to manipulate the information to tackle the required skills. This candidate, however, for the most part avoided this practice. The Moderator checked one of the web sites that had been used and found that the candidate had extracted, summarised and manipulated relevant material from over 60 web pages and 30 images, a mammoth task! – and yet the candidate still fails to meet some critical elements of Skill **A**.

Skill **A**

Coursework based on secondary resources is always very difficult to assess, especially where the data is mostly in literary format offering the candidate little scope for analysis and manipulation, beyond simple editing and summarising. That said, this candidate appears (at first sight) to fulfil all the demands up to and including 7b (assuming entry for AS rather than A2), on the grounds that many of the techniques listed in the descriptors are not really appropriate for this investigation. The Moderator, however, only awarded 4 marks for the skill, because most of the deductions and conclusions that could be made using the evidence gathered, were already expressed on one of the web sites used. Thus the candidate had little opportunity to meet the 'b' section of each descriptor using his own interpretive skills. **Centres need to be aware of this danger** and carefully plan their exercises and advise their candidates accordingly. In fact, the Moderator could justify offering even fewer marks.

Suggested mark: 4

Skill **E**

Although a much smaller amount of work is submitted for this skill, the candidate does actually cover all the descriptors needed to achieve full marks.

Suggested mark: 7

Exemplar Investigation 3

Investigating the origin of five mystery sediments

Investigating the origin of five mystery sediments (Skills I and A)

(Based on Module2832)

Instructions to candidates

Skill **I**: Implementing
Skill **A**: Analysing

Before you attempt this exercise you should familiarise yourself with the full details of skills **I** and **A** *(these were provided for candidates by the centre.)* Your written submissions must clearly cover the requirements detailed on the sheets.

Apparatus: Set of geosieves, electronic balance, microscope, dilute HCl acid, goggles, bivariate scattergram of index of sorting plotted against skewness for five sediments of known origin.

Safety: You must wear goggles if you use dilute HCl acid. Make sure that the sieves are firmly bonded together before you start shaking them. During the shaking process take a rest when needed to avoid putting excess strain on elbow joints, forearms, wrists and hands - if you have any weaknesses in these areas get someone else to do the shaking for you!

Task: Your main aim is to determine the likely depositional environment of five sediments (A to E) of unknown origin using grain size distribution, composition and angularity.

Hypothesis: Having read your theory notes you should be able to create one or more hypotheses testable by the analysis of data derived from sieving, microscope analysis and reaction with dilute HCl acid.

Method: You will need to sieve each sediment, recording the weight % trapped by each mesh and use appropriate methods to show the grain size composition of the sediments. For each sediment calculate the Index of Sorting and the Skewness. Plot your results onto the bivariate scattergram and suggest the likely origin of each mystery sediment. Where the grain size distribution analysis is inconclusive you will need to look at any other evidence which may help to establish the origin of the sediment.

Conclusions: These should be carefully explained in the light of the data available using appropriate geological terminology and discussion of sedimentary processes. You also need to establish the extent to which your original hypotheses are proved or disproved.

Evaluation: You will also need to evaluate the reliability of the data and the methods which you have used, discuss their limitations and make suggestions about how this problem could be solved more effectively. How useful is a bivariate scattergram of sorting against skewness for identifying depositional environments?

Exemplars of candidates' work

*This exercise was attempted candidates who had completed Module 2832. The teacher had already discussed with the class the requirements of Skills **I** and **A** and had gone through a 'worked exemplar' for them on another topic, which they were not allowed to repeat.*

CANDIDATE A

Investigating the origin of five *mystery* sediments

Aims and theoretical background of this research

Grain size analysis enables a great deal to be found out about sediment samples. This is done by passing them through a set of sieves whose mesh sizes show a regular decrease from top to bottom. The grain size distribution of a sediment can give some indication of the type of transportation and deposition. Sediments which consist of similarly sized grains are said to be well sorted and this is normally due to currents of water or wind. A long transportation process can also cause good sorting and vice-versa. As far as deposition is concerned coarse grained sediments are usually deposited in high-energy environments such as fast rivers and storm beaches, while fine sediments are deposited in low energy environments like lagoons and sheltered bays. The main aim of this investigation is to determine the types of sedimentary rocks and their palaeoenvironments by sieving and analysis of grain sizes, shapes and if necessary composition. I aim to test the hypothesis that **"It is possible by analysis of sediment sorting and skewness to determine the type of sediment and its depositional environment".** This might be expected because different transporting mediums process sediments to a different extent, e.g. ice - not much at all, wind - a great deal. Ice transports all materials in the same way whether they are boulders or pieces of clay, but wind transports sand along the ground or by saltation and silt and clay by suspension in the air. On a beach the regular breaking of waves processes sediments every day so they are often well-sorted, but a river may vary its flow over much longer time periods so the sorting would not be so good. Geologists have plotted the skewness and index of sorting of some known sediments onto a bivariate scattergram and shown that certain depositional environments produce certain characteristics. I will plot the data for my sediments onto the same graph and see which fields they plot in.

Method

The apparatus used included a stack of sieves, electronic balance, microscope, dilute HCl acid and goggles. I sieved each sediment for 10 minutes and weighed the contents of each tray on the electronic balance. 200 grams of each sediment was tested using sieves calibrated on the "phi scale". The figures were then halved to give percentages.

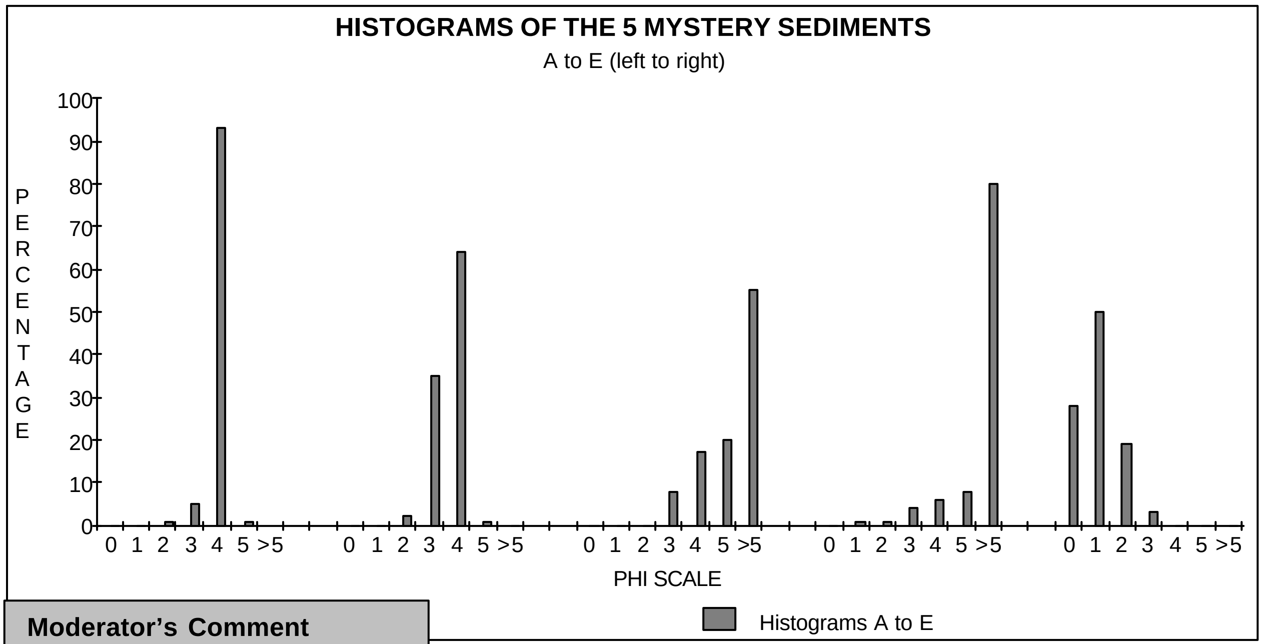
Safety

There were few safety issues with this investigation. Goggles were worn when testing sediments with dilute HCl. Otherwise the only *danger* was dropping the sieve stack while shaking.

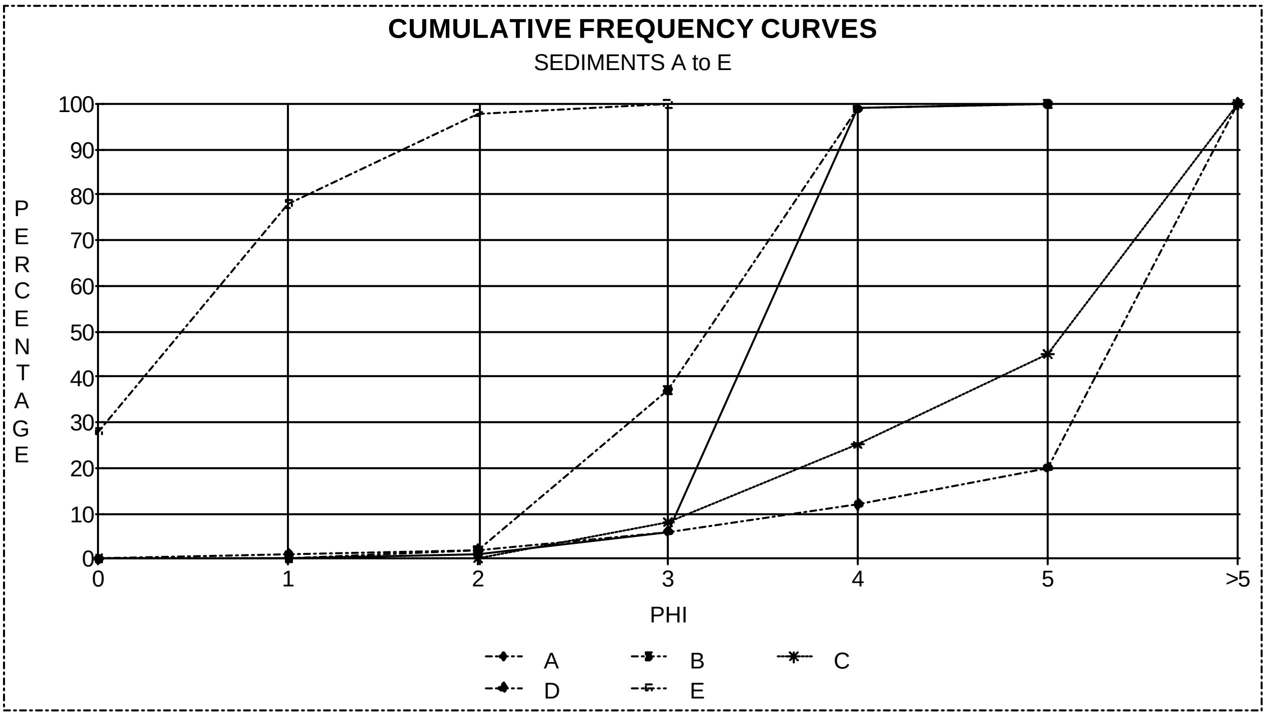
Results of sieving

				Samples						
Sieves	Width of mesh (mm)		Phi Value			A	B	C	D	E
1	1	0	0	0	0	0	28			
2	0.5	1	0	0	0	1	50			
3	0.25	2	1	2	0	1	19			
4	0.125	3	5	35	8	4	3			
5	0.063	4	93	62	17	6	0			
6	0.032	5	1	1	20	8	0			
Residue	<0.032		>5		0	0	55	80	0	
Means (phi)			3.1	3.1	5.5	7.7	0.5			

Candidate A then went on to produce 5 simple histograms (graphs 1 to 5) using one side of A4 for each, with % of grains on the vertical axis and the phi scale 0 to >5 on the horizontal axis. To save space these have been redrafted here as one graph. The cumulative frequency curves represent graph 6.



Moderator's Comment
Plotting data from several sediments onto one graph is good practice as it allows comparison.



Analysis

The index of sorting and the skewness for each sediment was then calculated using the formulae:-

$$\text{Sorting} = \frac{\Phi 84 - \Phi 16}{2} \qquad \text{Skewness} = \frac{(\Phi 84 + \Phi 16) - (2 \times \Phi 50)}{2}$$

Interpretation of the index of sorting

<0.35	Very well sorted
0.35 to 0.5	Well sorted
0.5 to 1	Moderately sorted
1 to 2	Poorly sorted

Interpretation of skewness values

+1.0 to +0.3	Very positively skewed
+0.3 to +0.1	Positively skewed
+0.1 to -0.1	Normal distribution
-0.1 to -0.3	Negatively skewed
-0.3 to -1.0	Very negatively skewed

Candidate A showed her calculations for each sample - the results are summarised in the table below.

Sample	Index of sorting	Description	Skewness	Distribution
A	0.37	Well sorted	0.00	Normal
B	0.68	Moderately well sorted	-0.13	Negatively skewed
C	1.13	Poorly sorted	-0.51	Very negatively skewed
D	0.68	Moderately well sorted	-0.26	Negatively skewed
E	0.90	Moderately sorted	0.01	Normal

In order to represent the results two types of graphs were used, histograms which enable a visual representation of grain sorting and skewness for individual sediments and cumulative frequency curves which can all be plotted onto one graph so that the sediments can be compared. With the cumulative frequency curves the steeper they are the better the sorting is

Sediment A (shown on graphs 1 and 6) has an index of sorting of 0.37 making it well sorted. Its skewness is zero meaning that its grains have a normal distribution. Plotting this onto the bivariate scattergram sediment A falls into the same field as coastal dunes in Lincolnshire so it is likely to be a wind deposit. Dune sands from desert environments are usually mature due to long transportation causing them to become well sorted and well rounded. Most sediments in deserts are initially deposited by water from occasional rainstorms. when the sediment dries out the wind picks up the smaller particles like sand and silt and transports them away leaving the coarse material behind. Sand particles move normally by rolling or saltation and stay close to the ground, but the finer particles of silt and clay get blown up into the atmosphere. When the wind slows down the sand is deposited but the fine particles in the air keep moving. This causes the good sorting in aeolian sandstones.

There is a problem with this sample - how can we tell if it is a true desert sand or from sand dunes around the coast like those in Lincolnshire. Desert sands are usually stained reddish brown because of the presence of haematite but this sediment was just an ordinary sand colour. Desert sands consist mostly of quartz because it is a hard mineral which will stand up to attrition. Beach sands can have a bigger variety of minerals and tiny bits of broken seashells which are made of calcite. To find out if sample A had any calcite in it I put some of the sand onto a glass slide and put one drop of dilute HCl on it. There was a strong reaction so this sand must contain calcite, therefore it cannot be a true desert sand. I also saw in the microscope that some of the grains were quite angular unlike what would be expected from desert sands. This could be because the particles have not suffered as much erosion as they have only been transported by wind from the beach. Some of the angular bits could be calcite because calcite has a cleavage and will tend to break along the cleavage plains rather than become rounded by collisions.

Sediment B (shown on graphs 2 and 6) has an index of sorting of only 0.68 making it moderately well sorted. Its skewness of -0.13 means that it is negatively skewed. Plotting this onto the bivariate scattergram sediment A falls into the same field as 'beach 2' in Lincolnshire so it is likely to be a beach deposit. Other reasons may be that it is not as well sorted as Sediment A but much better sorted than the River Trent sediments, so it is unlikely to be a river deposit. Beach sediments are generally quite well sorted because they are subject to regular wave action every day as the tide goes in and out. There is a big problem though proving a sediment is from a beach using grain size because it all depends where abouts on the beach the sediment has come from. Close to the high water mark sediments tend to be coarser and they gradually get fine towards the low water mark. This is because sediments near the high water mark are only affected by the sea at high tide, therefore all their processing is the result of wave action, i.e. higher energy. Further down the beach where the water is deeper at high tide the waves do not break so little energy is available to move sediment. This allows finer particles to settle. Another problem is that beaches vary a lot. A beach exposed to big high energy waves might only have coarse sediments but one sheltered from these may be made up of only very fine grains sometimes mud like Weston-Super-Mare. I also tested this sediment with acid to see if there were any shell fragments in it but there was no reaction. The grains looked sub-rounded in the microscope which is consistent with a beach environment.

Sediment C (shown on graphs 3 and 6) has an index of sorting of 1.13 making it poorly sorted. Its skewness of -0.51 means that its distribution is very negatively skewed having mostly fine grains but a tail of coarser material. Plotting this onto the bivariate scattergram sediment C does not fall in any of the fields of known sediments. Its mean grain size of phi 5.5 suggests that this sediment is silt rather than sand, therefore it must come from a lower energy environment. It is better sorted than the River Trent sand but worse than the beach sands of Lincolnshire. Sediment C might have come from an estuary because this is where rivers flow into the sea and estuaries are often low energy environments as big waves are rare.

Sediment D (shown on graphs 4 and 6) has an index of sorting of 0.68 making it moderately well sorted. Its skewness is -0.26 degrees so it is negatively skewed with more finer grains than coarse ones. Plotting this on the scattergram sediment D falls very close to sediment B and could fit with either of the Lincolnshire beach sands. Its mean size, though, is only phi 7.7 (silt) so it cannot come from an ordinary beach. The acid test shows that it contains no calcite. It could come from a lower energy area within an estuary than Sediment C or it could even be from boulder clay. There are no boulders and few grains of medium sand, but it a great deal of the sediment passed right through all the sieves into the bottom tray so it must be very fine. Even with the microscope it was difficult to see how angular the grains were but the bigger ones did look a bit angular. Angular grains are typical of glacial deposition.

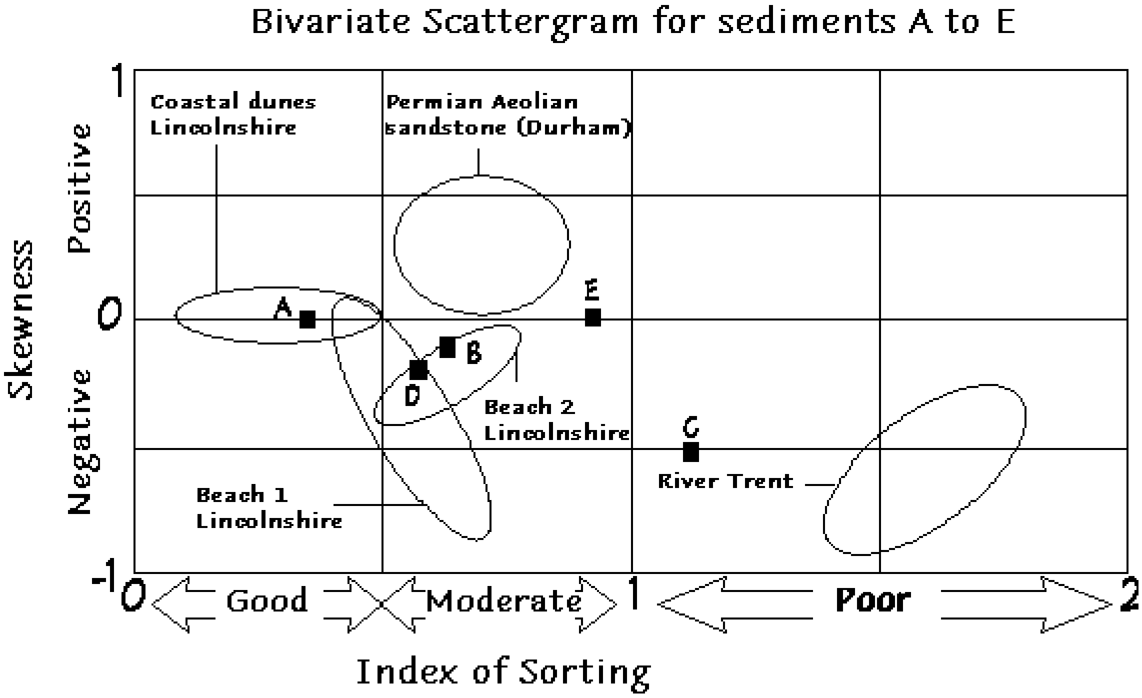
Sediment E (shown on graphs 5 and 6) has an index of sorting of 0.9 making it moderately sorted. Its skewness is close to zero meaning that its grains have a normal distribution. On the scattergram sediment E does not fall into any of the known fields. Its mean grain size of phi 0.5 shows that it is a coarse sand so it is unlikely to be aeolian as this would be medium sand. The particles were sub-angular in the microscope so this suggests some sort of river deposit as beaches tend to have sub-rounded grains. Also there was no reaction with acid.

Conclusions and evaluation:

The results show that my original hypothesis "It is possible by analysis of sediment sorting and skewness to determine the type of sediment and its depositional environment" has not been completely proved. Sorting and skewness do help to indicate sediment type and depositional environment but many other factors are important, e.g. grain size - sediments could have identical figures for sorting and skewness but if their grain size is very different then it is likely that they have a different origin. The shape and angularity of the grains also needs to be considered and also the mineral composition of the sediment. The bivariate scattergram is not that much help as there are not many types of deposit shown in the known fields and they all come from England. Sediments A to E may have come from totally different parts of the world with different climates and depositional processes. Also the crushed Permian aeolian sandstone does not seem to have the sorting and skewness values that would normally be associated with desert sands. This could be due to the inclusion of very fine broken up haematite cement along with the sand grains.

The results of sieving also have to be treated with some caution as 10 minutes might not have been long enough to ensure that all the sediment had got into the right tray. Some of the sieves got blocked with grains and there may be some errors in the weighing.

The investigation could be improved by plotting more sediments of known origin onto the scattergram and adding the mean grain size for each field. More detail could be included about the beaches sampled, e.g. where on the beach was the sample taken from? Using a mechanical sieving device and sieving for longer would also be better.



CANDIDATE B

Investigating the origin of five *mystery* sediments

Introduction and Aims

For this experiment we had to work out where five unknown sediments came from. This was done mostly by sieving to work out the grain size distribution which might tell us where and how they were laid down. Different types of transportation cause different amounts of sorting, e.g. wind causes much better sorting of sands than waves but waves cause better sorting than rivers. This is because the different transport processes operate in different ways. Some do not really involve much sorting at all, e.g. glaciers; all they do is carry clay, sand and even boulders in just the same way. The wind though picks up the very small particles into the air and moves them by suspension. It causes sand grains to hop along the surface by saltation. When it slows down the sand is deposited but the fine particles keep on blowing and are laid down somewhere else, separate from the sand. This is how the wind sorts sediment. Grain size is also an indication of the place where rocks were laid down, e.g. with bigger grains this indicates more waves or faster currents and small grains like clay and silt are laid down in a sheltered place like a lake. My hypothesis is "Grain size distribution can help to show where and how a sediment was laid down". Some special tests can be carried out on grain size distributions like the index of sorting and skewness. I will use these to compare the sediments.

Apparatus, method and results

Apparatus: sieves, balance, microscope, acid and goggles.

Method: 200 grams of each sediment was sieved for 5 minutes, then the material from each pan was weighed and the figure divided by two to give a percentage (as shown below).

Results:

Phi Value	A	B	C	D	E
	Samples				
0	0	0	0	0	31
1	0	0	0	2	51
2	2	1	1	3	16
3	6	37	9	4	2
4	91	61	17	7	0
5	1	1	19	10	0
>5	0	0	54	74	0
Average	3.9	3.6	4.8	5.4	0.9

The fact that figures all indicate slightly larger grain sizes than those provided by Candidate A may be a reflection of the fact that the sieves were only shaken for 3 minutes each. Another possibility is that the sieves were not cleaned and brushed prior to use, resulting in clogged mesh preventing sediment from passing down the sieve stack. Candidate B then went on to produce 5 simple histograms in much the same style as Candidate A (See previous example), and 5 ***separate*** *cumulative frequency graphs which made comparison rather difficult, partly defeating the object of the exercise.*

Interpretation of the results

The sediments were then tested for index of sorting and the skewness using the formulae shown below. The results are shown in the tables.

Sorting = $\frac{f84 - f16}{2}$ Skewness = $\frac{(f84 + f16) - (2 \times f50)}{2}$

Sorting

Sample	Index of sorting	Description
A	0.19	Very well sorted
B	0.48	Well sorted
C	1.20	Poorly sorted
D	0.96	Moderately sorted
E	0.54	Moderately sorted

Skewness

Sample	Skewness	Distribution
A	-0.14	Negatively skewed
B	0.08	Normal
C	-0.53	Very negatively skewed
D	0.30	Positively skewed
E	0.00	Normal

Sediment A is very well sorted (0.19) and only slightly negatively skewed. When it was plotted onto the scattergram it is very close to the coastal dune sands from Lincolnshire and not really close to any of the other sediments. So this must be a dune sand and its good sorting has been caused by wind. I did test this sand with acid and it reacted, so there might be calcite present. This could come from broken shells.

Sediment B is not quite so well sorted but it is still good with an index of 0.48 and a skewness of 0.08 which shows a normal distribution. This rock is a problem because it plots where the dune and beach one sands overlap, so it is difficult to be sure where it comes from. There was no reaction with dilute HCl acid so the sand must be all quartz.

Sediment C is very negatively skewed with a figure of -0.53, and it sorting is poor (1.2 on the scale). It doesn't plot anywhere near the known areas on the scattergram. It is quite fine grained though so it might have come from a sheltered area like a lake or a protected bay on the coast.

Sediment D is only just moderately sorted (0.98) and is positively skewed (0.3). It falls a bit to the right of the crushed aeolian sandstone from Durham, but with sorting this bad it is difficult to believe it was laid down by the wind. I used the microscope to look at the grains but they were still very small. A few of the bigger ones looked a bit angular so this rock is not likely to be aeolian.

Sediment E with an index of sorting of 0.54 is moderately sorted. Its skewness is zero so it has a perfect normal distribution. On the graph sample E falls in between four known fields but not exactly in any of them. It has an average grain size of 0.9 phi so it is quite coarse and unlikely to be aeolian. There was no reaction with acid.

Conclusion

My hypothesis that "Grain size distribution can help to show where and how a sediment was laid down" has not been proved properly. Using skewness and sorting sediments can be plotted onto the scattergram but they don't always match with the known sediments. This means that other methods must be used to work out where the samples came from. You could look at the minerals present and the colour of the rock to help.

The method used for the experiment was OK but shaking the sieves all the same amount was difficult so there may be some errors. Some of the grains might not have got to the place they were supposed to. If there was a machine to shake the sieves more evenly it would have been better. If more known sediments were on the graph it would also help.

Moderator’s assessment of Candidate A’s work on the five mystery sediments

Skill **I**

Candidate A conducted the investigation with great competence and confidence. Her observations and measurements are highly accurate, detailed and recorded clearly and in an appropriate format. She addresses the few safe issues involved in this experiment. She needed no staff help during the investigation.

Suggested mark: 7

Skill **A**

Candidate A rigorously analyses all the data available using the full range of graphical and numeric techniques in an appropriate manner. Her conclusions are very well balanced, comprehensive, concisely expressed and well supported by both geological knowledge and understanding, and the available evidence. She makes good use of geological terminology and her spelling, punctuation and grammar are all accurate.

Suggested mark: 8

Moderator’s assessment of Candidate B’s work on the five mystery sediments

Skill **I**

Candidate B conducted the investigation with reasonable competence but no great confidence (often required staff assistance). His data, however, do reach an acceptable level of accuracy (given that he either did not clean out the sieves properly before use, or did not shake them for long enough) and are recorded clearly and in an appropriate format. No comments about safety are made in the submission, but the candidate was observed to have followed all the required safety precautions. His failure to show confidence with practical techniques means that he does not fulfil all the requirements for 5a, and he certainly did not achieve the levels of precision or skill required to fulfil 5b.

Suggested mark: 4

Skill **A**

Candidate B makes good use of grain size, sorting and skewness but only limited use of composition and no use at all of colour and angularity. His histograms are effective and well interpreted but the fact that the cumulative frequency curves are plotted as separate different graphs for each sample is a weakness. He makes quite effective use of statistical techniques and interprets the results quite well. His conclusions are balanced but not particularly well supported by geological knowledge and understanding. Geological terminology is quite well used and spelling and grammar quite acceptable. He clearly achieves the requirements of descriptors 5a & 5b and all those preceding, but falls well short of those for 7b.

Suggested mark: 6

Exemplar Investigation 4

An investigation into the igneous intrusions of Arran

An investigation into the igneous intrusions of Arran (Skills I and A)

(Based on Module 2832)

Instructions to candidates

Skill **I**: Implementing

Skill **A**: Analysing

As with its other coursework exercises, the centre designed this exercise to assess all four skills. This policy was pursued to give candidates the best chance (in the opinion of the centre) of achieving a high overall mark. Only the marks for the highest scoring skills were actually submitted to the board. For an evaluation of the pros and cons of this approach see the earlier section on designing coursework exercises.

The purpose of this exercise is to investigate the origin of the igneous intrusions outcropping on Arran. After examining the BGS map of Arran you should be able to develop hypotheses about the origin of the intrusions. On the field trip, you will have a chance to visit and collect data from many localities where dykes outcrop on the beach, and use it to test your hypotheses. As a minimum you should make a rock description of each dyke, noting its composition, orientation, size and structures. You will also have an opportunity to visit the large Doon Sill and the Granite of the Central Ring Complex.

<u>Before leaving for Arran</u>

1. Study the geological map of Arran carefully
2. Identify the main igneous rocks which outcrop on the island.
3. Describe the outcrop pattern you have observed. (You may use a sketch map to help you)
4. Suggest a theory that would explain how the outcrop pattern you have observed may have been formed.
5. Read the requirements of each of the *Skills* on the sheets provided

<u>Before writing your hypothesis you should prepare yourself by reading:</u>

1. Your class notes - to revise igneous rocks
2. Pages 27-31 Geologists Association Guide to the Isle of Arran
3. Pages 44-57 Macgregor's Excursion Guide to the Geology of Arran
4. Pages 247-250 the section on the geology of Scotland in Dynamic Stratigraphy of the British Isles (Anderton)

In the field

You should use standard techniques to record geological data, but you will find it helpful to record dyke data in table format. You should carefully design a table and include it in the back of your notebook.

Written Report

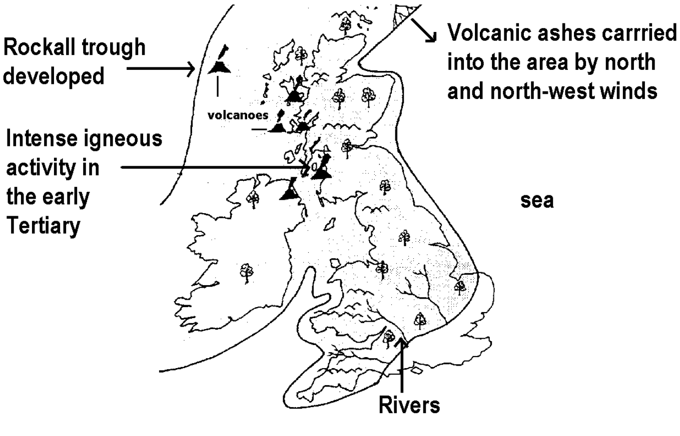
A detailed written account of your hypotheses, including a full explanation of your reasoning supported by background information. This can include evidence from the map, or information given by centre staff. You should also include a detailed plan outlining data collection, measurements, observations, use of any specialist geological equipment, etc. After a section on analysis you should state the conclusions you have come to and carry out a thorough evaluation of the methods you used, any modifications that you may have made in the field, and a recognition of any limitations to the evidence you have been able to collect. Your field notebook will be used as evidence of you observations, along with a detailed account of your results. You will need to produce Rose diagrams to analyse your data and draw any conclusions you can from them. Conclusions that are drawn from your results should relate to your original hypotheses and be backed up with any evidence from the literature.

An investigation into the igneous intrusions of Arran

Aim: To find out the origin of the igneous intrusions outcropping on Arran.

Introduction

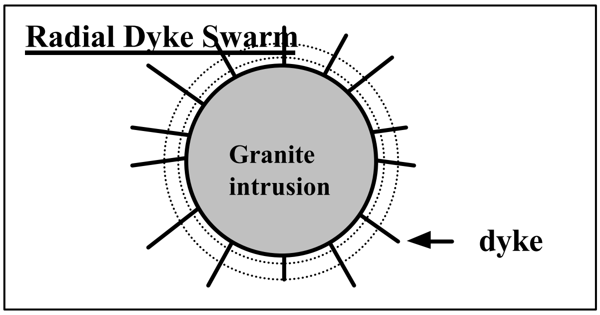
The Atlantic Ocean began to open between W. Africa and the United States approximately 2OOma in the Tertiary, thus having a direct effect on the British Isles, where rifting began. I believe, the cause of the dyke swarms present in Arran was because at this time there must have been high rates of heat flow in the mantle, and extreme tensional forces present in the overlying continental crust as Britain became separated from Greenland. The split took place along a line to the northwest of the line of convergence which was present during the Palaeozoic. All this tectonic activity would then give rise to great amounts of diverse igneous activity.



The igneous activity followed a pattern which is illustrated by the eruption of flood basalts. Following this was the intrusion of plutonic rocks, this in turn being followed by the intrusion of the dyke swarms which trend in a northwest - southeast direction.

Hypothesis

I predict that the dykes found associated with the Northern Granite intrusion form a radial dyke swarm (as shown below). I believe this because when the granite batholith was emplaced, it caused numerous fractures to radiate outwards as a result of forceful intrusion. Later on in geological time i.e. in the Tertiary when igneous activity was at its greatest, the magma sought out these fractures, and so dykes developed within them.



I also believe that because there are both acidic and basic dykes present on Arran, there must be more than one type of magma chamber. I predict that there is a magma chamber which produces basic magma, therefore it would be found deep within the crust, and one chamber producing acidic magma, which would be found much higher in the crust.

I also predict that the dykes to the south of the island will follow a NNW - SSE trend because they would have formed as a result of the failed fault system.

Apparatus: hand lens, compass clinometer, chalk, grain size card, tape measure, spirit level, nail

Method

This investigation was carried out at numerous locations within Arran, including Drumadoon, and the south coast. The rocks which were being studied were of igneous origin, mostly in the formation of dykes. Location one was chosen and here I decided I would study the area and draw on both a macroscale-including all the major rock features, such as colurnnar jointing, fractures- and a micro-scale- this enabled the rocks to be studied closely and allowed for a more accurate interpretation of their composition, structure, and formation. I drew important structures from the rocks such as vesicles, phenocrysts, fractures; and a through examination of the rocks' grain size, mineralogical composition, colour etc was undertaken and recorded.

At each location I took a dip and strike measurement from a bed at the site this being undertaken using the following method:

1. A suitable bed was chosen.
2. The spirit level was placed on the bed and moved until the bubble was exactly in the middle of the liquid cylinder.
3. Once this had been reached, a chalk line was drawn along the longest axis of the spirit level.
4. The compass clinometer was placed horizontally with the edge of it against the surface of the rock facing in the direction of the bed. *The candidate included a diagram to show this procedure*.
5. The compass was tilted up or down until the arrow pointed to North.
6. The housing was then moved round so that it fitted over the needle (which was facing north).
7. A reading was taken from the little arrow present on the outside of the housing.
8. The compass was then lined up to 90^o and placed vertically at 90^o to the strike line with the face of the compass in the direction of the bed. *A further diagram was included here*.
9. A reading was taken from the black arrow inside the housing. This was the dip measurement.
10. Finally the compass was held flat in the hand and the housing was rotated until it fined over the needle, this information was then used to show the direction that the beds were dipping in.

At each dyke the following was recorded in a ready-prepared table:

- Grid reference
- Thickness
- Orientation
- Composition

Results

The candidate included the results for 69 dykes from 32 different grid references in table format. Some of the descriptions, mineral and rock identifications, etc. go beyond what is required for Module 2. He also included a rose diagram showing the orientations of all the Arran dykes on the BGS map and a further three rose diagrams for specific locations:

- *The Northern Granite*
- *The south coast*
- *The Drumadoon Sill*

The style of the rose diagrams was much the same as that shown for the Fox Bay exemplar. The style of the table is shown below.

Grid Reference	**Thickness (m)**	**Orientation**	**Composition**
027205	30	170°S	Coarse, basic, porphyritic, pyroxene present – augite
	7.9	148°SE	Multiple basic, fine grained basalt in coarse-grained dolerite
	0.3	146°SE	Basic, fine grained basalt
	0.6	146°SE	Basic, fine grained basalt

The candidate then goes on to elaborate on specific locations as shown below

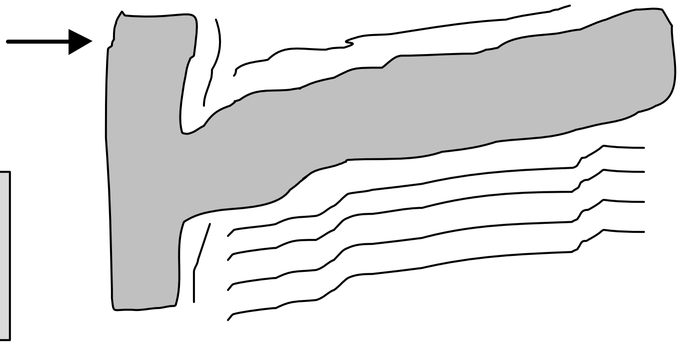
Grid reference: 883286

At this location a multiple dyke can be observed. The top unit is black, fine-grained, basic in composition. There are crystals of quartz which were identified by their hardness and glassy appearance. Separating the top unit from the bottom unit is a chilled margin. The bottom unit is also black and composed of phenocrysts of quartz and feldspar within a finer-grained groundmass of Rhyolite. Within this unit there are occasional xenoliths. These xenoliths are a brown/red colour. The rhyolite is softer than the basalt.

Two appropriately labelled, scaled and titled photographs of the above were included here to support the above descriptions

From my results of the dyke measurements taken at Kildonnan, I can see that there has been a definite crustal extension of at least 146.67m. Around Kildonnan there was some interesting dykes which had bifurcating structures. They could be seen at grid references: 016209 & 016210. These dykes have resulted from the magma exploiting several of the fractures which were present in this one small location. There is also an indication here that several phases of intrusion have occurred.

The magma has exploited other fractures present to produce this bifurcating structure

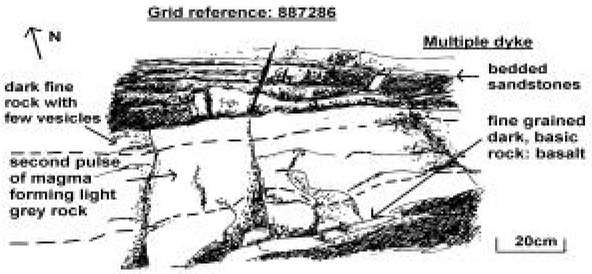


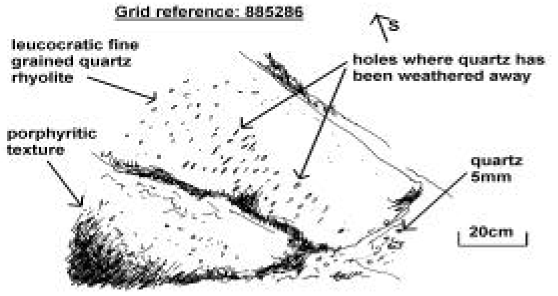
Teacher's Comment
Where is the scale on this diagram? Further labels are needed.

At grid reference 885313, near the Drumadoon sill, there is an interesting crosscutting relationship between the three dykes present. The first one is a multiple dyke being composed of quartz feldspar porphyry and porphyritic basalt on the outside. The dyke itself trends in a WSW direction. The second dyke cuts through the first, however this time the composition is basaltic, but still trending in a southwesterly direction. The third dyke cuts through both of the dykes mentioned previously at north westerly, 203° angle. This dyke is also basic in composition, however it does include some phenocrysts of quartz.

In some places such as grid reference 887286, there is evidence of several phases of intrusion. The dyke here is a bit confusing. The dark fine grained basalt at its edges does have a chilled margin at its contacts with the country rock, but the lighter coarser rock in the centre of the dyke, although it has a sharp margin with the basalt, does not show any evidence of chilled margins itself. This suggests that the basalt was still hot when the second pulse of magma came

In other places, such as grid reference 885286 there was good evidence of a porphyritic texture. The phenocrysts of quartz were up to 5mm in size but were rather rounded. In some places they had been weathered out to leave holes. This is difficult to explain because quartz is a very resistant mineral, usually the last one to suffer weathering.





Conclusion

At grid reference 883286 the top unit is black, fine-grained, basic in composition, thus meaning that it is basalt. There are crystals of quartz, which were identified by their hardness and glassy appearance. Separating the top unit from the bottom unit is a chilled margin (see tracing overlay). The bottom unit is also black and composed of phenocrysts of quartz and feldspar within a finer-grained groundmass of rhyolite. Within this unit there are occasional xenoliths. These xenoliths are a brown/red colour indicating the presence of iron rich minerals.

The way in which the phenocrysts developed in the magma was either due to fractional crystallisation or assimilation. With fractional crystallisation there is only one magma chamber, and the basic minerals, such as Olivine and Amphibole are first to crystallise. Once these minerals have developed they sink leaving a liquid magma that is more siliceous. The magma is therefore composed of 90% basic material and 10% acidic material.

The candidate included a diagram of Bowen's Reaction Series here to support his arguments

The second theory is that the phenocrysts developed as a result of assimilation. In this case there is still one magma chamber, but the crust surrounding it undergoes stoping. It is as the crust becomes incorporated into the melt that the crust becomes contaminated and becomes composed of 90% basic material and 10% acidic material. However, the dykes in Arran are composed of 90% acidic material and 10% basic. This means that two magma chambers are required: one which is deep in the crust to produce basic material (forming the basaltic dykes), and one chamber in the upper crustal areas to form the acidic magma (forming the rhyolitic dykes).

Because there are different types of rock present at this location, this indicates that there must have been two different magma chambers present to cause the basic and acidic dykes found on the island.

The rhyolite is softer than the basalt. The quartz feldspar porphyry (the bottom unit) has parts of the above quartz basalt within it, thus indicating that the basalt must have been there first.

The majority of dykes which have been studied seem to have been formed by the dilation of a fracture. As the sidewalls of the country rock move apart, the magma is intruded. The majority of dykes observed show a distinct chilled margin, this developing as the magma first comes into contact with the cold country rock and cools very rapidly to a fine-grained crystalline rock. Towards the centre of the dyke it becomes significantly coarser-grained, this for example can be seen in the dykes appearing around the area of grid reference 019209. The reason for this is because as more magma is fed into the dyke along the axial zone, the fissure continues to dilate. The magma is more thermally insulated by the presence of the surrounding hot magma (instead of cold country rock), and so it cools more slowly to form a more coarsely crystalline igneous rock.

The dykes seem to be concentrated into swarms 10-15km wide and, in general, those in the north of the island are thinner and less numerous than those in the south.

The candidate included a simplified map of Arran showing a radial pattern of dykes around the Northern Granite, the Central Ring Complex and the dyke swarms of the south coast.

The reason for the NW–SE trend of the tertiary dykes may be due to the British isles being once part of a failed oceanic ridge, or part of a line fracture which occurred at an angle to the ridge. The dykes would have then been intruded into these fractures, caused by a twisting movement of the sea floor as it continued to separate.

The candidate included a simplified labelled map of the British Isles indicating the stress patterns and identifying the directions of the principal stresses in relation to the NW-SE trend of Tertiary dykes.

From my results of dyke measurements and my rose diagrams, I can confirm that the dykes around the Northern Granite intrusion do radiate outwards, therefore they must follow lines of weakness which were created when the stock was emplaced. Some of the dykes found in Arran were multiple, composed of both acidic and basic magma, indicating an origin from two distinct magma chambers within the crust. These dykes followed fractures created as Britain became a part of a failed rift system. The rose diagrams illustrate clearly that the dykes follow a significant NW-SE trend, strongly related to the fault system and crustal extension during the Tertiary.

In conclusion, I can see that the dykes studied in Arran vary in thickness from 0.3m to 30m. The dykes are either composed of acidic rock or basic rock; the basic rock would have formed from magma deep in the crust, where as the acidic magma was from a chamber higher in the crust. The general trend of these dykes is in a NW-SE direction, perpendicular to the stretching of the earth's crust in an NE-SW direction during plate movement.

Evaluation

The results which were gathered from the study of the dykes were as accurate as possible. When measuring the orientation of the dykes, I noticed that the needle was deflected. This was because the dykes are composed of iron rich minerals which effect the magnetic field. Once I had realised this, I modified my method straight away, and commenced with carrying out my recordings next to the dyke, instead of on top of it.

The time available at each site was limited because of the number of sites we chose to visit during the week. If more time was available, then more detailed rock descriptions could have been carried out, with structures and features present within the rocks being examined thoroughly, and a much wider range of dykes could have been observed from all around the island. I believe that the results gathered were reasonably accurate given the time limitations. If it had been possible to have thin sections made of the rocks this would have allowed a more accurate set of results, and it would have aided my interpretation. But this method of analysis would be too expensive and too difficult to carry out. If tests, such as the acid test, had been carried out on the rocks then this would have helped me in my understanding of the composition and conformation of the dykes and veins studied. Other factors, such as erosion and weathering of rocks and the availability of fresh surfaces, made it difficult to gain valuable results and difficult to draw valid conclusions. However, these difficulties did not cause any major observational problems, or reduce my ability to observe the rocks in quite good detail.

Bibliography

The British Isles through Geological Time by J.Lovell

Geological Science by McLeish

Principals of physical geology by Duff

Geology of Arran by MacDonald & Herriot

Moderator’s assessment of the Arran coursework

Skill **I**

The teacher’s comments show that the candidate worked with precision and confidence, followed basic safety rules and recorded his information clearly. The candidate clearly justifies the top mark.

Suggested mark: 7

Skill **A**

The candidate meets all the descriptors up to and including 5b. His conclusions, however, while being broadly justified are not very well structured and at times his grammar made understanding his explanations quite difficult. The grammar and spelling were partially corrected to allow inclusion of the exemplar in this guide. His rose diagrams gave a clear visual image of preferred dyke directions, but lacked a scale.

Suggested mark: 6

Exemplar Investigation 5

Porosity and permeability experiment

Porosity and permeability experiment (Skill P and E)

(Based on Module 2833, Component 01)

Instructions to candidates

Skill **P**: Planning
Skill **E**: Evaluating evidence and procedures

Before you attempt this exercise you should familiarise yourself with the full details of skills P and E (these were provided for candidates by the centre.)

Your task is to devise a method of assessing the porosity and permeability of a variety of rocks, put it into action, evaluate the data it generates and the methods you used. You should also discuss the relevance of porosity and permeability to economic geology. For this, you might consider its impacts on:

- water supply, springs and aquifers
- reservoirs and leakage below dams
- oil reservoir rocks within an oil trap
- underground mining-especially coal-and the flow of water in mines
- waste disposal in quarries and the flow of leachate into water supplies
- civil engineering: water tables flooding and the stability of slopes

Pages 72-73 of Geological Science by McLeish may provide some useful ideas from which you might formulate hypotheses. As a starting point, you may wish to consider hypotheses which relate porosity and/or permeability with one or more variables, such as grain size and shape, degree of sorting, pore space, packing, cementation, rock type, etc.
You can choose from the equipment listed below to design experiments to test hypotheses. If you fell you need any further equipment please ask one of the Geology staff.

sieve stacks
unconsolidated sediments
containers of different shapes
stop watches
newton meters
plastic measuring cylinders
bungs
clamp stands
plastic beakers
calipers
balances
filter paper
plasticine
cotton wool
funnels
marbles of different diameters
a variety of grains and pulses
plastic tubes

Porosity and permeability experiment

Introduction

Porosity is the percentage of the total volume of a rock that consists of open spaces, called pores. It determines the amount of water or oil that a given volume of sediment can contain and is affected by the size, shape, sorting and compaction of grains. Although porosity affects the passage of fluids through rocks, a high porosity does not necessarily mean a high permeability as the latter is also affected by the size and continuity of pores.

Porosity and permeability play a large part in the storage of oil and gas within reservoir rocks. To be a good reservoir, a rock must by very porous so that it can contain large enough volumes of oil or gas for profitable commercial extraction. A reservoir rock should also be very permeable so that the oil can flow through it.

As oil floats on water in a reservoir rock, it will float upwards to the water table and will be lost at the surface unless there is a suitable cap rock. This has to be impermeable and preferably non-porous.

The candidate included a good labelled diagram of a typical anticline trap here to illustrate her ideas.

Hypothesis 1: Porosity will increase as particle size increases
I think this will happen because larger particles will mean bigger pore spaces.

Hypothesis 2: Permeability will increase if grain size increases.
I think this will happen because larger particles will mean bigger pore spaces and the water will flow through more easily. Also, permeability will increase as the particle size increases because of molecular attraction, which is the force that exists between a solid surface and a film of liquid. It causes the liquid to adhere to the solid despite the force of gravity. Where pores are small, films of liquid on adjacent grains come into contact with each other, extending the force of molecular attraction across the whole pore and preventing a throughflow of liquid. In sediments which have a larger grain and pore size, this does not happen, so the liquid can flow through.

Hypothesis 3: Porosity will decrease as the particles in a rock become more poorly sorted.
I think this will happen because the smaller particles will fill in the spaces between the larger ones.

Another diagram was included here to show these principles

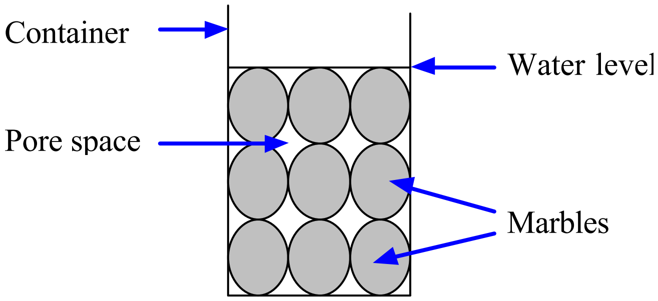
Aim: The main aim of this project is to test the two hypotheses I have stated

Method 1

1. A size of marbles was chosen and these were put in a suitable container in which the volume of water could be measured.
2. Water was pored into the container until it just covered the top marble.
3. The total volume of the marbles and water was measured and recorded.
4. Next, the water was poured off into another container to find what the volume of the pore space was, using the formula:

Porosity = (volume of pore space x 100) / volume of total rock

In order to minimise experimental error the process was repeated three times for each size of marble, and mean values were taken. The experiment was repeated for a series of different sized marbles. The volume of the marbles was also calculated by measuring the diameter, finding the radius and applying the formula for the volume of a sphere (4/3Π r^2), so the actual porosity as well as the effective porosity was found.



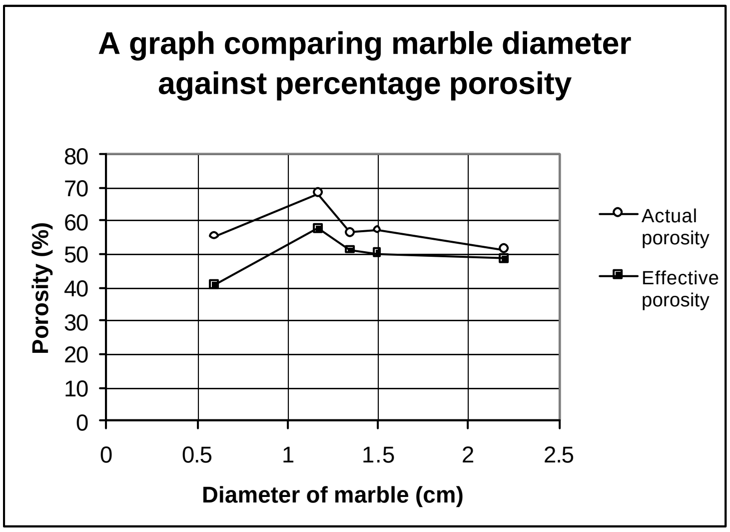
Results for porosity and marble size

Diameter of marbles (cm)	Number of marbles	Volume of marbles	Volume filled to (ml)	Volume poured off (ml)	Actual porosity (%)		Effective porosity (%)	
0.6	19	2.15	5	2.5	57		50	
0.6	19	2.15	5	2.5	57	55.4	50	40.7
0.6	19	2.15	4.5	1	52.2		22.2	
1.17	34	28.5	90	50	68		55.5	
1.17	34	28.5	92	54	69	68.3	58.7	57.6
1.17	34	28.5	90	53	68		58.8	
1.35	85	109.5	250	125	56.2		50	
1.35	85	109.5	252	130	56.5	56.4	51.6	51.2
1.35	85	109.5	252	131	56.5		52	
1.5	57	100.73	235	117	57		49.8	
1.5	57	100.73	240	126	58	57.2	52.5	50.2
1.5	57	100.73	232	112	56.5		48.3	
2.2	17	94.8	200	100	52.6		50	
2.2	17	94.8	190	90	50.1	51.4	47.4	48.6
2.2	17	94.8	200	97	51.5		48.5	

The table on the left and the graph (below) both show that the effective porosity is lower than the actual porosity. This was to be expected because in reality there will always be some pores that do not get filled with water because of air bubbles or because a pore space is isolated from others.

There does not seem to be much of a relationship between grain size and porosity because at first the line goes up but then it goes steeply down and then starts to level out. The pattern of porosities for the actual porosity is slightly different from the effective porosity. Where the porosity for the marble size of 1.5cm is higher than that of the marble size 1.35 on the actual porosity line, it is lower than the marble size of 1.35cm on the effective porosity line.

Conclusion



My results show that there does seem to be a pattern between marble diameter and porosity, but that the pattern is that the porosity increases as marble size decreases. So, the hypothesis has to be rejected. I had forgotten that although the size of the pores increases with the size of the marbles, the number of pores is less. My results show this quite well, but I think the irregular pattern in my results is because the marbles did not settle into a cubic packing style as shown on my earlier diagram. Some of the pore spaces were a funny shape. One marble size fitted into the container in a rhombohedral packing arrangement, while the others all fitted in a different way producing very mixed results.

The effective porosities are lower because of experimental error, i.e. some of the pores did not get filled with water. The actual porosity calculated mathematically was more accurate, but the effective porosity is of more value to geologists because in nature not all of the pores would be filled or able to hold oil.

From this investigation I found which rocks geologists would need to look for in the hope of finding oil reserves. A reservoir rock has to have high porosity and high porosity rocks are fine grained, e.g. clay, which can have up to 50% porosity. A good cap rock can have very low porosities and therefore large grain sizes, e.g. sands and gravels which only have porosities of around 20% (Porter & Skinner)

Evaluation

My method did have several inaccuracies: -

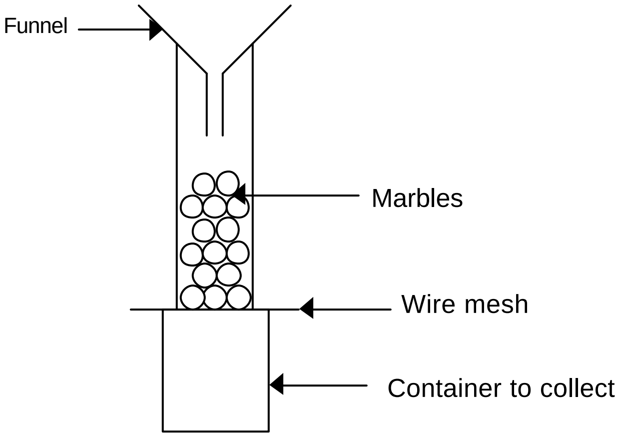
- In transferring water from one container to another some would be lost.
- I think that I did not keep all the variables the same, e.g. the packing was different with different marbles. I would try to keep it the same if I did the experiment again. I might shake the marbles until they all settled as low as possible. This would make rhombohedral packing more likely. Id would also force out any trapped air.
- If I tried the experiment again, I would also use more different sizes of marbles and I would carry out an experiment to see how different packing affects porosity.
- Another problem with my experiment is that I made the assumption that all particles are perfectly round and spherical. In real rocks this would not be true. I would like to test the porosity of real sediments next to see if there is much difference. It would also produce much better results for geologists who are looking for oil.

<u>Method 2</u> (to test if permeability increases with grain size)

For several marble sizes: -

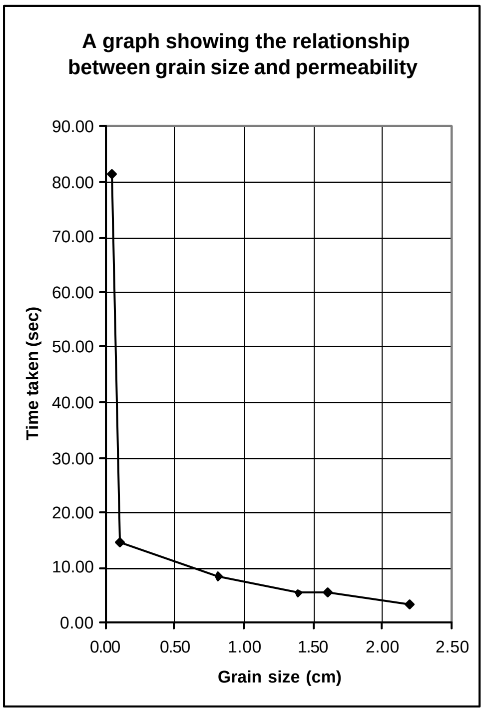
1. A wire mesh was put over a container and then an open-ended cylinder was placed on top.
2. The cylinder was filled with one size of marbles up to a specific mark.
3. A funnel was then placed on top.
4. $50cm^3$ of water was then poured into the top of the funnel and the time was recorded until all the water had come into the container below the cylinder.

The procedure was repeated three times and mean values taken to ensure accuracy, and sand was used for the finest grain size. The sand was saturated with water first to make sure that molecular attraction was minimised.



Results for permeability and particle size

Particle type	Mean diameter of particle (cm)	Time taken for water to pass through (secs)
Marble	2.20	3.58
Marble	1.60	5.51
Marble	1.40	5.27
Kidney bean	0.83	8.34
Pearl barley	0.12	14.61
Sand	0.05	81.30


A graph showing the relationship between grain size and permeability

<u>Conclusion</u>

The graph shows that there is a direct positive relationship between permeability and grain size. As the size increases the time taken for the water to pass through gets less. The rate of increase in much greater at the finer end of the scale. This follows what Porter and Skinner say about molecular attraction across pore spaces, i.e. smaller particles have smaller pore spaces in which molecular attraction extends across the whole pore, making it difficult for water to pass through the sediment.

This means that a cap rock needs to be impermeable to stop the oil passing through. So, very fine rocks like clay or shale would be best. A reservoir rock would need to be permeable to let the oil flow in.

Evaluation

Inaccuracies could result from:

- transfer of water between containers
- use of pearl barley and kidney beans, as these are not spherical.

To improve the experiment it would be best to standardise on grain shape and use different sized marbles throughout.
I would also measure how much water flowed through the sediment in a fixed time rather than how long it took for all the water to pass through.

I would also like to find the grain size at which molecular attraction expands right across the pore. Any grain size above this would mean that the rock would be permeable.

Another problem with the technique is that oil has different physical and chemical properties to water so it may behave differently with respect to pore size.

Method 3 (to test whether porosity will decrease as sediments become more poorly sorted)

The candidate reproduced method 1 but with various mixtures of marble size. The results were a little erratic but there was a general trend supporting the hypothesis. Her approach to the work was systematic and supported by appropriate graphs and diagrams. She carried out a thorough evaluation showing great awareness of the limitations of the approach.

Moderator's assessment of the porosity and permeability work

Skill **P**

The candidate's work easily satisfies all descriptors, up to and including 5b and probably just about does enough to satisfy 7a and 7b, but does make a few rather simplistic assumptions. However, a simulation of this type is clearly limited in how far it can go to match reality and the candidate shows ample awareness of this. The fact that he comes to some wrong conclusions based on the evidence should not bar him from achieving a good mark on Skill **P**. Furthermore, his spelling, grammar and punctuation are all accurate.

Suggested mark: 7

Skill **E**

The work clearly justifies the top mark for this skill, meeting all the demands of each descriptor.

Suggested mark: 7

Exemplar Investigation 6

Geophysical survey – A quarry investigation

Quarry investigation (Skill P and I)

(Based on Module 2836, Component 01)

Instructions to candidates

Skill P: Planning
Skill I: Implementing

Your task is to investigate the geology, extraction operations and socio-environmental impacts of Heaton Quarry, a working sand and gravel quarry owned by Bluestone Aggregates. While at the quarry site you must abide at all time by the safety instructions given by the management.

Before you attempt this exercise you should:

1. familiarise yourself with the full details of skills P and I (these were provided for candidates by the centre.) and you must develop a coherent plan explaining your approach to this investigation before you visit the quarry.

2. make use of the base map provided

3. process and interpret the borehole data for the thickness of the deposit supplied by the quarry management.

Your final report should be handed in to your teacher three working weeks after the visit.

Quarry Investigation

An investigation of Heaton Quarry

Planning

This report aims to investigate the geology, extraction operations and socio-environmental impacts of Heaton Quarry, a working sand and gravel quarry owned by Bluestone Aggregates.

Methods:

To investigate the extraction and processing operations of the quarry the following techniques will be used:

- Interview the quarry manager and some of the staff
- Take photographs of the quarry and each of the key the extraction processes

To investigate the socio-environmental impacts of the quarry the following techniques will be used:

- Interview quarry staff and managers to find out their opinions
- Questionnaire survey of local residents
- A letter to the local planning department
- Photographs to show negative and positive effects of the quarrying and subsequent reclamation.

To investigate the geology the following techniques will be used:

- Collect samples of sediment from the quarry for sieving (see later details of method)
- Analyse the grain size distribution, sorting, colour and thickness of the sand and gravel deposits
- Suggest the most likely origin of the sediments

Safety Considerations

At all times, whilst in the quarry the standard safety regulations required by the quarry owners will be applied. These will include wearing a hard hat and a reflective jacket to wear (*candidate included a labelled photograph of students and quarry staff in protective dress*).

We will need to be aware of quarry traffic and keep away from working machinery.

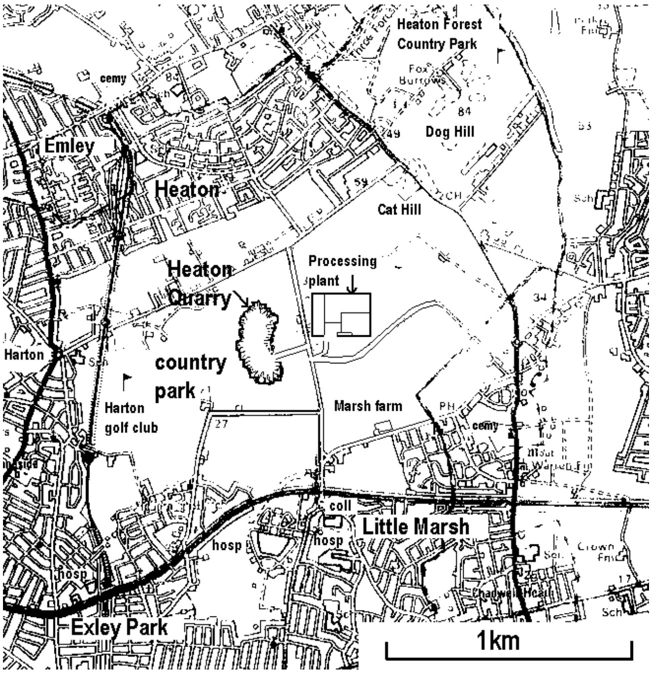
While investigation the geology of the site we will avoid climbing up the quarry walls, which are very unstable and stay away from boggy and flooded areas.

Introduction

Heaton Quarry lies on the edge of a major conurbation, within a small semi-rural setting, but surrounded by light industry and suburban residential areas (see the map on the next page). Around it are a few fields, two country parks and a golf course all of which are valuable ‘green’ resources for the large urban population. The existence of the quarry is due to the large national and local demand for aggregate for constructional materials.

The ground on which the quarry stands is leased to the company by the local authority and a local farmer, for the duration of the extraction process. Once extraction is complete it will be returned to the previous owners five years after the quarry has been filled back in as required by law. For the farmers, the land is actually greatly improved after the quarrying because not only the soil had a good chance to re-energise itself but also before it was dug up there were good patches and bad patches of growth. After the soil had been re-laid, all the patches would have been mixed together and therefore would create a field where growth would be homogeneous.

In this specific instance, the life expectancy of this quarry is 11.94 years. This can be calculated from a standard formula that is used in calculating the extraction of aggregates of this sort. *The candidate explained this calculation in an appendix to the main report and also included field sketches of the area in current use plus two areas that have yet to be excavated and four labelled photographs* showing salient features.



Heaton quarry and its surrounding area

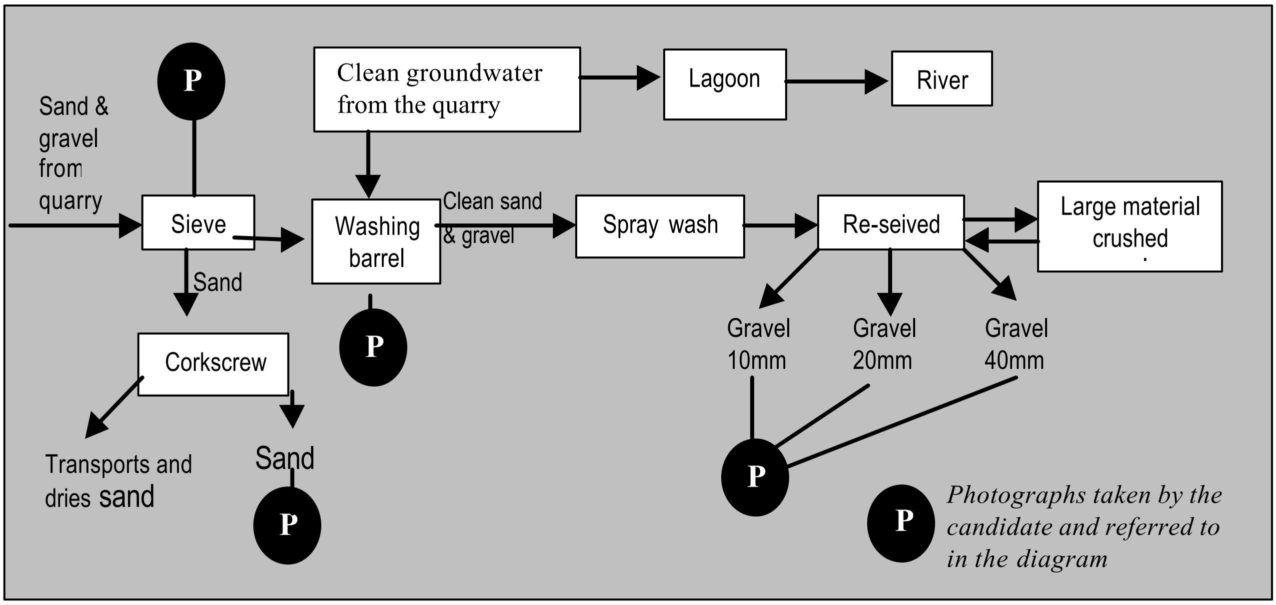
The map clearly shows the environmental sensitivity of the quarry. It is surrounded on almost every side by residential areas and lies within a green resource which includes a farm, golf club and two country parks.

Transportation of the produce from the quarry cannot avoid passing through the residential areas and it is unlikely that any expansion of its operations would be politically acceptable to the local council or the residents, despite a large and increasing demand for sand and gravel in the region.

Teacher’s Comment
The candidate has made good use of the map and explained its relevance.

Quarry Operations

Most workers arrive at their work at 6:30am with the machinery being started at 7:00am and finishing at 6:00pm. Seven people are employed at the processing part of the operation, with another fifty subcontractors being needed to help run the quarry site smoothly. The process used to separate the sand and gravel is shown in the flow diagram below.



Bluestone Aggregates spends tens of thousands of pounds on security to warn people of the dangers they could face in he quarry and to try to discourage them from entering. Security measures include six miles of fencing and warning signs both on the inside and the outside of the quarry site. If someone does injure themselves in the quarry, but did not have the authority to be in there, Bluestone is unlikely to be held responsible as they have taken the required precautions.

It could partly be because of this that the profit level for the company is quite low. They must therefore avoid any unnecessary costs. For example, contamination of the soil caused by the water from the neighbouring river, which used putressible rubbish to fill in the quarry that was once there. (Putresible rubbish costs £10 in tax per ton, but companies can charge for rubbish to be dumped).

The sand and gravel that has been extracted for over six years now is used locally in the construction business and forms an important economic supply of raw material to the area. The sediment is transported no further than 12.2 kilometres (8 miles) due to it being a relatively cheap material to buy and because it is quite bulky. Costs have to be kept to a minimum, as the profit level is low.

To begin quarrying, all the overburden has to be removed to allow access to the sand and gravel. It costs £1 for each metre cubed removed. The topsoil and sub soil that makes the overburden is then placed in a pile that surround the site. These piles are called bunds and are used to cut the amount of noise emitted from the quarry and also to disguise the operation from those outside. *The candidate included a labelled photograph of a bund to illustrate her argument..*

Once quarrying has been completed in each area, Bluestone can only replace the sand and gravel with inert material such as concrete and rubble (which costs £2 in tax per ton). The company will then look after the land for a further five years to make sure nothing has penetrated into the ground that should not be there, such as poisonous chemicals. To check for this, tests are carried out via boreholes that had previously been placed into the ground. If the land has passes each check it is returned to the original owners.

In one area of the quarry, a previously unknown Roman burial ground has been discovered. Until the local authority give permission, which would first require an excavation of the site and removal of the bones, aggregate from this area cannot be extracted. *The candidate provided a photograph of this site.*

Groundwater is a major problem that has to be dealt with at the quarry. Left alone, the water table will emerge level with the top of the layer of gravel and would therefore seriously disrupt the extraction process. Bluestone has to pump out this water 24 hours a day so the amount of noise the pump emits has to be taken into consideration. This is why a super silent pump is used (it is so quiet, that it is possible to hold a conversation right next to it while whispering!).

The water is then transported to a water settler where the solids that are suspended within the water sink to the bottom. Some of the resulting clean water is then used to clean the sand and gravel in the washing barrel (see the flow diagram). The rest of the water is put into a lagoon before finally ending up in the nearby river.

Environmental Issues

The candidate included a copy of a well-designed questionnaire and a table summarising the results, which are discussed in some detail before the following summary is given.

There are numerous environmental impacts that arise as a result of the quarry.

1. Noise. This poses a problem to the surrounding residents, albeit a low-density residential area. When this type of extraction is first proposed, it is always a worry to the local population that there will be excessive noise and congestion from lorries. This problem always has to be addressed by the extraction company to the satisfaction of the local authority. If any sort of noisy work is to be carried out, leaflets are posted through the doors of those effected to tell them of the company's future plans. One way Bluestone Aggregates keeps noise to a minimum is by using a super silent water pump. This could be seen as especially important because the pump is active 24 hours a day. The bunds that acts primarily as a screen barrier also cuts the level of noise that is emitted from the quarry. (See photograph number 2).
2. Dust and din. The trucks exiting the quarry are liable to be carrying mud on their wheels. If this is not removed, it would be taken onto the local roads where the wet mud could be dangerous as it would give a reduced amount of grip to other road users. The dust could find its way into peoples gardens and homes and could lead to a complaint towards the company. To solve this problem, there is a lorry bath just north of the lagoon where the vehicles have to be washed before leaving the quarry area. (See base map for location).
3. It prevents the farmer from farming. This is an obvious impact for the farmer who owns the land. Compensation is paid to the farmer so he/she does not loose out financially. When the land is returned, it is done so with the same amount of topsoil and sub soil and no adverse pollution because the ground had been repeatedly tested.

4. The big hole in the ground. (See photographs number 3 6). With quarrying this is inevitable. To compensate for this, bunds are erected around the site using the overburden in order to hide it from public view. Once quarrying has been completed in each area, the company has to return the site back to how it originally looked.
5. It evicts animals. Rabbits and other wildlife use this ground. However, even though it may seem harsh on the wildlife, they are only affected in local areas and simply end up moving onto a new location. The quarrying actually helps birds such as Sand Martins as they need vertical sandbanks to nest in, exactly what the quarrying provides.
6. The risk of contaminated water from the nearby river seeping into the quarry. If this happens, it is the law that Bluestone has to clear up the contamination and not the owners of Fairlop Waters. To prevent this from happening in the first place, a wall of clay dug out from the quarry is erected between the two sites and acts as an impermeable layer through which water cannot pass. (See base map to discover where the wall is).

Social issues:

The major social issue here is that the quarry creates numerous amounts of jobs. This means that more people will have disposable income and therefore is more likely to spend more money, which will help the economy both locally and nationally.

Economic issues:

Economically, the supply of the sediment is very important as the surrounding eight miles the quarry delivers to is quite densely populated due to it being just outside London. The quarry gives access to a local supply of construction material, therefore meaning that costs to those who use it are lower than if it was bought elsewhere. Again, the fact that the quarry creates a number of jobs means that those people are likely to spend more money.

Political issues:

There are groups of people who oppose the quarry and those who support it. Those who oppose it do so as they argue that it would destroy the local environment by creating a massive eyesore in the landscape and also because it could kill some of the local wildlife whilst destroying their homes.

Those who believe that the quarry is a good thing and support it, do so as they believe it will help the local economy mainly by creating extra jobs, but also because it would aid the construction business. This could lead to more businesses being attracted to that area and therefore creating more jobs. They may also be aware that once quarrying has been completed, the area must be returned to its original state and must not, under any circumstances, contain any pollutant. If some is found, the company excavating the quarry has to dig up the site again to remove it of the subsidence in question.

Palaeoenvironmental investigation

Sieving Exercise

Method: The following ten steps will be followed:

1. Using 7 sieves, each sieve will be weighed while empty and the result subtracted from the total weight of the sieve plus the sediment. The sieves will then be assembled in order of size (largest at the top).
2. The top sieve (32mm - 64mm) will be filled with sediment collected from the quarry site.
3. A lid will then be placed on the top sieve and held securely whilst the whole structure is shaken for 2 minutes. This is necessary so that sediment has a sufficient and standardised length of time to sift through each sieve.
4. Each sieve will then be separated and weighed and the results recorded.
5. The weight of the empty sieve will be deducted from the weight of the corresponding sieve containing the sediment. The final weights will be shown in a table (see below).
6. Any sediment which is too large to pass through the first sieve will be carefully separated manually into five different piles (32 - 64mm, l6 - 32mm, 8 - l6mm, 4- 8mm and 2 - 4mm). Each pile will be weighed and results recorded.
7. The percentage composition for each sediment size will then be found by dividing the weight of each sediment by the total weight of all sediments and multiplying that amount by 100.
8. For graphical purposes, each total will be rounded up or down to the nearest whole figure where possible. I will also work out the weight percentage cumulatively as I need this for the Y-axis.
9. The information will be plotted onto a graph.
10. The coefficient of sorting will then be calculated using the formula: $(\phi_{84} - \phi_{16}) / 2$ where ϕ_{84} is the cumulative weight of 84% of the sample and ϕ_{16} is the cumulative weight of 16% of the sample).

The candidate included a well-structured spreadsheet table showing her results and a cumulative frequency graph will the 16th and 84th percentiles drawn in.

Conclusion

After working out that the coefficient of sorting is 3.575, 1 now know that the sediment is very poorly sorted.

Description of the sediment

The rocks and sediment found at Heaton quarry has primarily been flint, fine sand, clay and ironstone. It is the orangey-brown colour of the iron that shows us the deposit is land based. The size of the clast is very variable (as proven by the sieve experiment) and therefore the sediment is poorly sorted.

The Tertiary clay found under the sediment is a lot older than the above deposit at around 50 million years old. With sharks teeth being found in it, it could be determined that the clay was laid down when a deep, calm sea covered the area.

The sediment that is found in the quarry was laid quite quickly and fairly recently (most probably during the time of the last glaciers - approximately ten thousand years ago). The reasons we are able to tell this is because the clasts are poorly sorted and poorly cemented. The fact that the sediment is poorly sorted shows that it was laid quickly because if the sediment took time to settle, the smaller, lighter particles would have been transported further than the larger, heavier clasts. The poorly cemented clasts shows that the sediment has not been settled long enough for a cement to take form effectively.

To transport such large clasts as are seen in the quarry, a high-energy flow of water would be required, e.g. a glacial meltwater stream. This then ties into the information stating that the sediment has been laid during the last glaciation. The deposit made by this process is called a fluvial glacial deposit.

The candidate included a beautiful coloured and detailed isopachyte map and cross sections showing the form of the deposit, produced by herself from borehole data supplied by the quarry management . Unfortunately these would not reproduce well enough in black and white to include in this guide.

The isopachyte map depicts a north-south trending deposit that clearly marks out a channel-like shape. The most likely event that would cause such a shape is a river, which is further evidence of what I have been stating.

Moderator’s assessment of the quarry investigation

Skill **P**

The work is quite difficult to assess against the mark descriptors for this skill. To begin with three separate aspects of the quarry are investigated, each of which requires its own set of plans. Furthermore, the extent to which candidates can create their own achievable or realistic plans is a little restricted with field-based exercises in general, and even more so where the extra safety issues associated with extractive industry have to be considered. However, at various points, she clearly meets all the demands of all descriptors up to and including 5a, 5b and 7a. Whether, she fully **justifies** her approach, including choice of equipment (see 7b) is doubtful.

Suggested mark: 5

Skill **I**

The work clearly justifies the top mark for this skill. The work was very well marked by the centre with helpful teacher’s comments which referred to the degree of accuracy of the candidate’s observations and measurements. She demonstrated confidence and competence in all the required techniques.

Suggested mark: 7

Exemplar Investigation 7

A comparison of fossil assemblages and palaeoenvironments in the Castleton area of Derbyshire

A comparison of fossil assemblages and palaeoenvironments in the Castleton area of Derbyshire (Skills A and E)

(Based on Module2834)

Instructions to candidates

Before the trip carefully read all the requirements of skills A and E.

The centre provided details of these for each candidate on handouts.

In the field, you will be visiting several localities in the Castleton area in order to work out the depositional environment. You will need to make a detailed study of the rock types paving particular attention to the fossil specimens found in order to make an interpretation of the palaeoenvironment. All the rocks you will see are of Carboniferous age. In the field we will be examining exposures between Winnats Pass and Mam Tor. At each locality you will need to:

Make field sketches to show any significant large-scale structures you see.

Make a detailed rock description commenting on the following

- Rock textures
- Sedimentary structures
- which fossils can you identify?
- how many fossils of each group are there?
- how are the fossils distributed?
- are the fossils whole or fragmented?
- what is the mode of preservation?

Between Treak Cliff and the reef knoll (one of the most fossiliferous sites in Britain) you will need to collect as much data about the fossils you find as possible to make a detailed interpretation of the palaeo-environment. You may wish to use the proforma included to help you organise your data.

The proforma was A4 size and had separate sections for the following observations:

- Location, grid reference & lithology.
- Fossils found in lenses or bands?
- Even distribution through rock unit?
- More abundant at any level through the unit?
- How many species are present?
- Relative abundance of different species?
- Any obvious derived fossils?
- All fossils preserved in the same way?
- Any delicate structures preserved?
- Worn or broken? Some more than others?
- Crinoid stems as isolated ossicles or long?
- Any preferred orientation?
- Any fossils in life position?

Your final written report should include:

1. an outline of the problems that you were trying to solve.
2. a detailed explanation of the field techniques used so that anyone else could use the . (This should include copies of any proformas used).
3. detailed rock descriptions at each site.
4. relevant field sketches or photographs.
5. drawings of the fossils you have found: detailed, fully labelled diagrams are essential to accompany your field observations.
6. analysis of fossil data collected, this may include tables or graphs.
7. interpretation of palaeo-environment of the Castleton area. You must include the evidence that supports your conclusions.
8. A thorough evaluation which recognises any limitations to your findings and suggests how these may be overcome if further research was to be carried out on this topic.
9. acknowledgements/biblography which recognises any secondary sources of data you have used.

A comparison of fossil assemblages and palaeoenvironments in the Castleton area of Derbyshire

The candidate submitted a 20 page document in which hand written field notes along with sketches, were included with the final word-processed report. Many of the larger sketches and some of the detailed rock descriptions have been removed here due to lack of space.

INTRODUCTION

During the Lower Carboniferous period the area which was to become Britain was just below the equator, so it would have been a hot tropical climate. Some of the countries that are now near to the equator have reefs forming around them so by looking at modern reef formations and the organisms associated with them we might be able to determine how a Lower Carboniferous reef was formed. Modern reefs are complete ecosystems having a structure made up of compound corals, algae, brachiopods, bivalves, sea urchin and crustacea. The corals which form these reefs can only survive in warm shallow marine waters where they live in symbiosis with algae. Many of today's reefs consist of a shallow shelf lagoon, a back reef, a reef wall, a fore reef and a deep-sea basin, so we may expect ancient reefs to be similar.

The candidate included a diagram of a typical Lower Carboniferous apron reef derived from a textbook.

Reefs often have several ecological niches (as shown in the diagram). The deep-sea basin may have fragmented fossils derived from the reef plus pelagic fossils. Fore reef areas face the open sea and therefore suffer much wave action providing clean aerated water and helping to wash away any debris which could cover the coral polyps. Fossils are the most abundant on here. Reef walls have the most calcareous algae they are the highest part of the reef enjoying the most sunlight. Reef walls have many other life forms but not as many as fore reef areas. Back reef and the shallow shelf lagoon are even less abundant in fossils because currents are weak so little fresh supply of planktonic food could be brought in for the organisms to feed on. Also, these areas often have cloudy water and suffer deposition of fine calcite and even clastic sediment debris, a situation which corals cannot tolerate.

Hypothesis: During the Lower Carboniferous period there was a reef formation in the Castleton area.

AIM: To test the hypothesis and to determine the geological history of the area by carrying out rock descriptions and identifying any fossils found between Winnats Pass and Mam Tor.

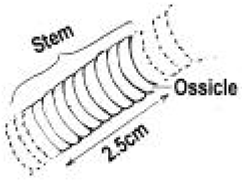
METHOD: Rock descriptions were carried out and field sketches were made at Winnats Pass, Treak Cliff and Mam Tor. The rock descriptions were based fossil content, grain size, composition and texture, using the proforma. The nature of the palaeoenvironment was then interpreted from this data.

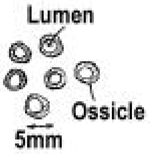
Winnats Pass

The candidate went on to draw a good labelled field sketch of this area and tried to explain the origin of the gorge. The rock description below was in tabular form, but has been condensed to save space.

Rock description: a granular, fine grained rock (but still over 0.01mm – visible crystals of sparite), random orientation of grains, pale grey, calcite (as it reacted with dilute HCl), fossil fragments make up 5 to 20% of the volume.

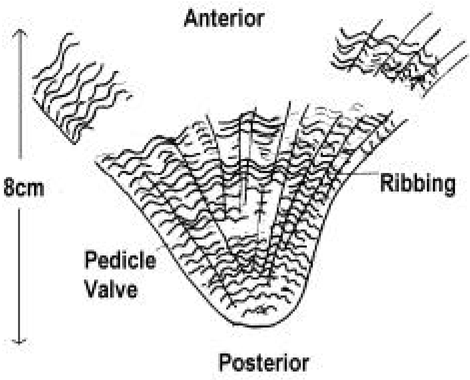
Fossil assemblage: The fossils were spread out evenly in the rock rather than concentrated in bands or lenses. At least four different species were found: crinoid, large brachiopod, orthid brachiopod and coral, of which the corals and small brachiopod fragments were the most abundant. There was no evidence of derived fossils and preservation appears to be cast and mould with possibly some replacement. Delicate structures were not preserved, only thick parts and strong ribbing. Most of the fossils showed evidence of abrasion or attrition but on the whole the brachiopods were less damaged. With the crinoids mostly isolated ossicles were seen but one stem of 9 ossicles was found. They showed no orientation and none of the fossils appeared to be in a life orientation. Sketches of some of the fossils are shown below.



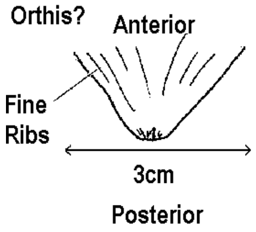


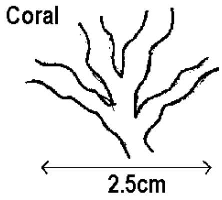
On the left is the stem of a crinoid. I don't think that this is the whole stem as there are only 9 ossicles. This also makes it difficult to identify for sure, but I think it could be Amphocrinus because this was common in the Lower Carboniferous reef limestones.

More often, isolated ossicles are found, making any attempt at identification impossible. The presence of crinoids indicates shallow marine conditions below the low water mark, as they will not tolerate any drying out at low tide. The fact that they are fragmented suggests quite strong wave or current action or



The drawing on the left shows a fragment of a very large brachiopod shell. It has distinct ribbing and a hint of growth lines. It is not preserved in enough detail for accurate identification, but given its large size and strong ribs it must have been able to withstand wave action and currents. It





There were also some small roundish brachiopods with fine ribbing and relatively straight hinge lines. This indicates that they may have lived in high-energy conditions. They may have been Orthids.

Small pieces of colonial coral were present but it was impossible to identify them. However, their presence does indicate a shallow marine environment. The specimen found may be Amplexus coralloides as these were common in the Lower Carboniferous in the Peak District.

Interpretation: This rock is sedimentary as it is made up of randomly arranged granules. It is a limestone as it is composed of calcite. Being over 0.01mm, the calcite granules are known as sparite. Sparite sparkles, unlike micrite, and indicates a high energy under water environment. The sparite is acting as a mineral cement between the fossil fragments. The variety and state of the fossils suggests a reef apron environment.

Treak Cliff cavern to the reef knoll

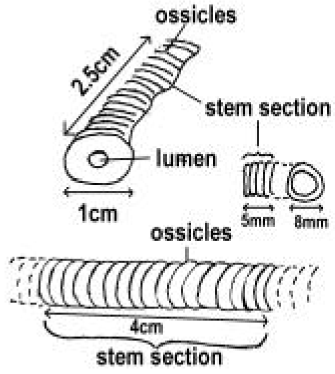
Another field sketch was included here

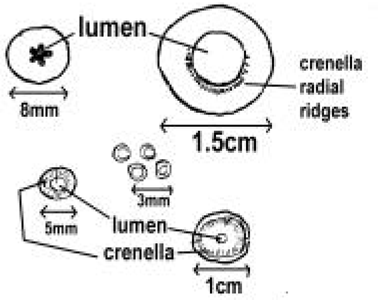
Rock description: The rock at Treak Cliff had a randomly orientated fine-grained granular texture with sparite present. It was pale grey and again reacted with dilute HCl acid and therefore it was calcite. There were many fossils within the rock, about 40% bioclasts.

Fossil assemblage: Again, the fossils were evenly distributed through the rock. There were crinoids everywhere, but Productids, Strophomenids & Rhynchonellids were only found in specific areas. The fossils became more abundant higher up the exposure, with around 13 different species present, including 7 different species of crinoid, 1 Orthid, 1 Productid, 1 Strophomenid, 1 Rhynchonellid, the bryozoan *Fenestella* and even the pygidium of a trilobite, probably *Griffithides*. The was no evidence of derived fossils. Preservation appeared to be mostly replacement and cast and mould. For some reason the degree of preservation was a little better than Winnats with more hinge lines and ornamentation visible. The brachiopods were mostly whole or only slightly damaged and longer crinoid stems were found (up to 4cms) but there were also a few separated ossicles in evidence. There was no real evidence of stratification or preservation in life orientation, except perhaps, the productids.

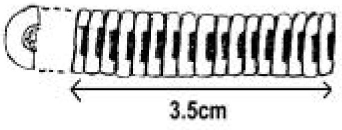
The fossils a Treak Cliff were far more abundant than the fossils found at Winnats pass. Although the fossils that were found at Treak Cliff were contained in the same sparite cement I think that this area was a slightly lower energy environment than at Winnats Pass because the fossils are far more complete and are better preserved in greater detail.

The area where the giant productids were found was surrounded in a different type of rock. It was much finer and whiter than the sparite and so preserved the productids in very good detail. I think that this rock may have been something like chalk which is very pure. Also some of this white rock had been percolated through by water so the calcite had been dissolved and then re-deposited as large calcite crystals. This percolating water may have been carrying the minerals that replaced the productid shells.

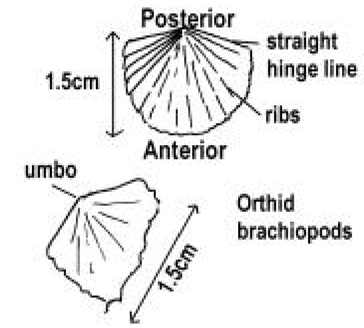




These fossils are all parts of crinoid stems. They are more complete than at Winnats Pass. They are difficult to identify accurately without the preservation of the crown, but it is obvious that there are several species due to the differences in the ossicles.

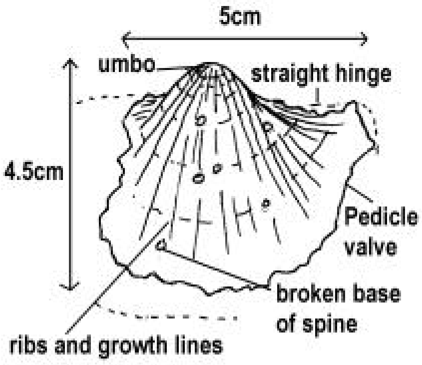


On the left is a crinoid stem which ahs been half eroded away. From this it can be seen that the preservation method is replacement. After burial the crinoid stem was replaced by other minerals so that the internal structures were preserved.



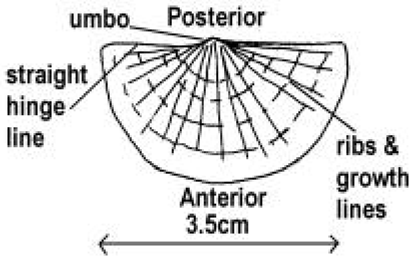
Orthid brachiopods

These brachiopods are orthids. They are very circular and they have straight hinge lines. This along with the ribs indicates a high-energy environment. These were most common in the Ordovician but did not become extinct until the end of the Permian, so they would have been around in the Carboniferous.



Productid brachiopod

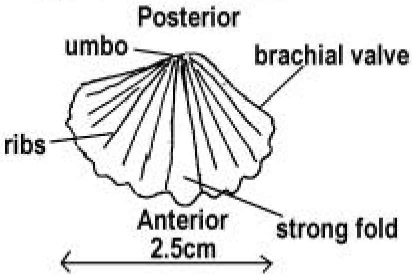
This brachiopod is a productid. These have a semi-circular outline and a long straight hinge line. The valves are thick and the pedicle valve is very convex, with a broad rounded umbo. Hollow spines once protruded from the valve but all that is left of these are small projections called tubercles. The spines were used to anchor the brachiopod to sea floor sediment. This again suggests quite a high-energy environment.



Strophomenid brachiopod

This brachiopod is a strophomenid. It has a straight hinge line and ribs indicating that it was not a burrower but lived on the surface in a high-energy environment. Strophomenids were most common between the Ordovician and the Devonian but there were still a lot around in the Carboniferous.

Rhynchonellid brachiopod



The brachiopod on the left is a rhynchonellid which is strongly ribbed with a very strong fold in the anterior margin to aid filter feeding. The strong ribs indicate a high-energy environment.

Teacher's Comment
Excellent well-labelled accurate diagrams and sketches, all with a scale and title.

This rock is a bioclastic limestone as it is made up of randomly arranged granules. It is a limestone as it is composed of calcium carbonate. The granules are greater than 0.01 mm in size so this limestone can also be classed as a sparite cement. The sparite shows that this site was once also a high-energy underwater environment. The dip of the rock was very difficult to measure, as bedding planes were hard to see. However, it seemed to be around 30^{o} to the northeast. This could be a non-tectonic dip resulting from deposition on the reef apron.

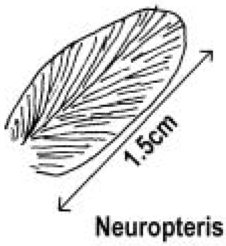
Blue John Mine to Mam Tor

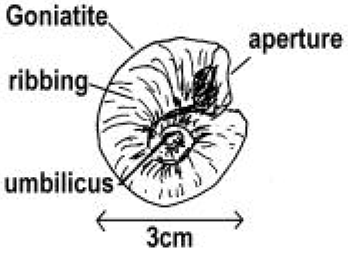
The candidate included another large-scale field sketch showing the structures in this area.

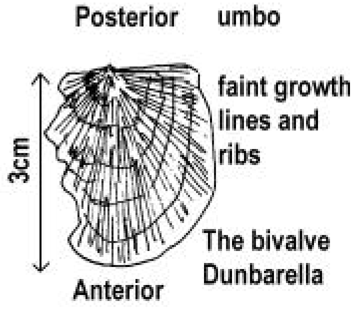
Near the Blue John Mine, in a streambed we found a very different rock type, black shale. The exposure was small but we found much larger deposits of it on the other side of the road.

Rock descriptions: The shale was very fine-grained, and almost black in colour but with some reddish rusty looking areas. It is impossible to comment on its exact grain size or texture, except that it is obviously an argillaceous sedimentary rock. It was very fissile often breaking up in the hand. It was extremely well bedded breaking up into laminae about 2mm thick. The mineral composition was probably clay minerals but a lot of carbon must have been present to give the black colour. There was also some iron pyrite in some horizons.

Fossil Assemblage: Much of the shale appeared to be completely unfossiliferous, but one member of our party found a layer that contained three fossil species. These were taken back to college and we were allowed to sketch and identify them. My drawings are shown below.







Interpretation: This was a very unusual fossil assemblage. The neuropteris is a land plant, a type of fern, but the goniatite and the dunbarella are both marine creatures. The preservation of all three seems to have been cause by replacement by carbon and on the neuropteris even quite faint veins could be seen. The shell of the dunbarella appears to be very thin. One possible interpretation of this assemblage is that it was laid down in an estuary where land plants could be washed into the sea and mixed with marine fossils. It must have been a low energy environment to allow the preservation of leaves and to account for the thinness of the dunbarella shell. The only other reason for dunbarella having a thin shell might have been that it was a burrower, but this is unlikely because it does not have a streamlined shape. The presence of iron pyrite and carbonised fossils really means that the environment must have been anaerobic/anoxic.

Mixed with the black shales were occasional **sandstone units**. These became thicker and more common further up Mam Tor.

Rock description: The sand stone as an arenaceous sedimentary rock of yellowish brown colour but with carbon rich layers in the bedding planes. It was moderately to poorly sorted, with occasional grains up to almost 2mm (mostly only 0.5mm) and examination with a hand microscope (25x magnification) showed up sub-rounded to sub-angular grains. Most of the clasts were quartz but there was also evidence of muscovite mica flakes and as there was no reaction with dilute HCl there must not have been any $CaCO_3$ present. Lithification seems to have been the result of cementation with limonite and silica. The base of the bedding planes included many sole marks, including flute casts, striations, prod marks and load casting. The flute marks seem to indicate transport from the northeast. Within the beds there was occasional evidence of current bedding.

The candidate included further diagrams and sketches to illustrate the sedimentary structures.

Fossil Assemblage: The only evidence of fossils we found was one piece of what looked like part of a branch of a tree. It was probably calamites.

Interpretation: The sandstone appears to have a fluvial origin, especially taking into account their sedimentary structures and the presence of calamites. However, it is difficult to explain why they are interbedded with the shales. This seems to indicate frequent changes from estuarine to river channel environments. It may be due to changes in sea level or isostatic changes.

CONCLUSION: My hypothesis was that a reef was forming at Castleton during the Lower Carboniferous. I think that the evidence that I found at Winnats Pass and Treak Cliff has proved this to be true, although only parts of the fore-reef seem to be present in these locations. The rocks at both of these sites were found to be limestone indicating shallow warm marine conditions. The limestones at both of the sites contained numerous bioclasts within a sparite cement. The sparite cement consists of relatively large granules which indicate that it was formed in a high-energy environment. As the rocks also contained a great number of fossils, which need a good supply of oxygen, then it can be assumed that they would have been quite near to the surface of the water so that they have had access to the oxygen which is dissolved in the water near to the surface.

The fossil brachiopods that were found at both of the sites all had the same features in common. They all had a relatively straight hinge lines and to varying degrees they all had ribbing on their thick shells. These features tend to indicate a high-energy environment as well. The crinoid fossils that were found were never complete with stems and crowns, but were either preserved as single ossicles or small sections of stem. This would indicate a high-energy environment as wave action could have broken up the crinoids after death.

A sure indicator of an ancient reef formation would be if fossilized compound corals were found. The only compound corals that were found were at Winnats Pass, but there were not huge amounts of coral found here though. I would have expected to find a great deal more compound corals at both Winnats Pass and Treak Cliff if this area was once a reef but the reason for this maybe because the structure was not largely built by corals as in modern reefs. The reef structure was possibly largely built by lime secreting calcareous algae instead of compound corals. It may be difficult to determine whether this was the case or not as the actual algae may not have been preserved.

There were very few organisms that were preserved in life position. This would indicate that organisms were not quickly buried by a sudden deposit of sediment, but after death calcareous algae may have slowly accumulated on top of them. This process may have aided in the replacement of some of the original hard parts of the organisms.

Some of the fossilized organisms found at Winnats Pass and Treak Cliff such as the Productid brachiopods, the Amphoracrinus crinoids and the Amplexus corals were at their most abundant during the Lower Carboniferous. The other fossil organisms that were found would have also been quite common during the Lower Carboniferous, but not have been specific to this time range. I think that this would almost definitely date the reef at Castleton to have been formed during the Lower Carboniferous.

Now that Winnats Pass and Treak Cliff have been identified as being a part of a Lower Carboniferous reef formation they can be specifically located to an area of the reef. The fore reef should have the most brachiopods and crinoids and not much algae. It should also be made up of steeply sloping beds of limestone. From this I deduced that Treak Cliff would be part of the fore reef as this site had the most crinoid and brachiopod species and does have steep dips.

The back reef should have less crinoids and brachiopods than the fore reef but more compound corals. It should also consist of slightly dipping beds of limestone. According to this information I believe that Winnats Pass was the back reef area.

The Palaeozoic Fossils book have termed the reefs found at Castleton and in the surrounding area as being 'reef knolls' that formed on a shallow sea platform which was a large block of Ordovician rock.

The origin of the reef knolls is still in dispute but some believe that they represent original mounds of carbonate mud on the sea floor which were surrounded by contemporaneous and younger shales. The reef knolls persist to grow at these sites, growing upwards so as to keep pace with the deposition of the surrounding sediments.

The sediments at Mam Tor show a definite stratigraphic break from the Lower Carboniferous reef limestones.

The lagoon with the reefs on the block of older Ordovician rock was a more stable platform than the rapidly subsiding basin. So as this basin was subsiding during the Upper Carboniferous the dark beds of shales were being deposited in a very low energy environment deep under the water. This is shown in the very fine grains and the iron oxide staining visible in the rock.

After a period of the basin subsiding it was then uplifted, or the sea level decreased, and this was when the sandstones were deposited. As the sea level was now low relative to the sea bed, the current would have been quite weak and a river flowing from a landmass to the north-east would have quickly dumped it's load as the current was not strong enough to carry the sand grains out to sea. This process would have resulted in the formation of a delta.

The area was periodically submerged below sea level to form the beds of shale and then uplifted to form the deltas and the beds of sandstone.

Further diagrams and maps derived from secondary sources were included to support the candidate's arguments

EVALUATION:

The evidence that I was able to find has indicated to me that the Castleton area was once a reef and a submerging basin. To make this conclusive I would have needed to find plenty of compound corals. As this was not the case I made the assumption that calcareous algae largely built the reef structure although I had no proof I would have to find further evidence to support this or I would have to try and find some compound corals.

The reason for why there were very few compound corals found on the day may have been because the locations were badly weathered and as this was a protected site we were not allowed to hammer at the limestone.

If there never were large amounts of compound corals found I would have to prove that the Castleton area was a reef by finding evidence of calcareous algae, this could be done by using a microscope.

I found that identifying some of the fossil specimens I found quite difficult if only a small part of the organism was left intact. When I came across this problem I would try to look for pictures of fossils in books that seemed to be very similar, then I would see if that organism would have been around during the Lower Carboniferous and whether it lived in a high energy shallow sea environment. Using this method would mean that I was already assuming that this was a reef environment and that I was making my results fit what I wanted them to. My guesses may have been correct but it would be better to go back to the site to try and find some better specimens that are easier to identify.

Another problem was the lack of continuous exposure. This made it difficult to examine all the strata in the succession, as did the terrain which was steep and rocky in places. At Mam Tor examination of all the beds was impossible due to the safety risks involved and the lack of time. This cliff is very unstable and rock falls are common, so we had to restrict our research to safe areas.

Despite these drawbacks, the evidence for the probable palaeoenvironments described is quite compelling and it is doubtful whether improved quality or quantity of data would have made much difference to the overall conclusions which could be drawn from the evidence.

Moderator’s assessment of the fossil assemblages work

Skills **A** and **E**

The candidate produces exceptional work for each skill and fully justifies full marks on each.

Suggested marks: Skill **A**: 8; Skill **E**: 7

Exemplar Investigation 8

Mapping and graphic logging at Lulworth Cove

Mapping and graphic logging at Lulworth Cove (Skills A and I)

(Based on Module 2835)

Instructions to candidates

In the field

1. Describe, in detail, the major rock types exposed at Lulworth Cove (Fossil Forest, SY830797 and west of the slip way, SY824798), Stair Hole (SY823798), Durdle Door (SY805802). Try to describe each rock type from a minimum of two separate exposures. Annotated field sketches or photographs and graphic logs are essential. Your rock descriptions should make reference to composition, grain size, grain shape, degree of sorting, colour, sedimentary structures and fossils (including details of preservation).

2. Make detailed recordings of the geological structures found within each rock unit, i.e. dip and strike of bedding, major joints, faults, etc.

3. Describe any special procedures and safety precautions which had to be followed.

4. Ensure that you use appropriate geological terminology wherever possible and take the necessary steps to maximise the accuracy of your data.

After the field trip

1. Use your data to create a geological map of the area ensuring that it includes a key, actual and inferred boundaries, ample dip and strike readings, and faults (observed and inferred).

2. Draw a representative north-south geological section for either Durdle Door or Lulworth Cove.

3. Describe the overall geological structure of the Lulworth Cove region. Rose diagrams or pie charts may be useful.

4. Interpret your geological map and cross section suggest a geological history for the sequence of rocks you have mapped.

5. Fully evaluate the methods you used to collect and analyse you data, identifying any limitations and their likely impacts on data quality and interpretation, and suggesting ways in which your research could be improved under better circumstances.

Mapping and graphic logging at Lulworth Cove

The following is a detailed description of the four main rock types that can be found within Lulworth Cove.

Purbeck Rock

The Purbeck beds were studied at SY821797, east of Lulworth Cove at the Fossil Forest and at Stair Hole: SY823798 and Durdle Door, SY805802, and the adjacent cliffs to the west at SY804803. The Purbeck beds are 146 million years old and can be split up into four separate groups as follows:

Top of the sequence	Broken beds (limestone)
	Soft cap (limestone)
	Dirt Bed (rending soil horizon)
Bottom of the sequence	Hard cap (limestone)

Below the "hard cap" is the Portland stone.

The candidate included a well-labelled field sketch of the Portland Stone drawn at Pulpit Rock, Portland Bill from earlier in the field trip.

Hard Cap

These limestones are none crystalline with a medium grey colour with a hint of yellow. They are very fine grained with thin beds on average 7.5cm thick. On the top surface of the Hard Cap are well-developed desiccation cracks and evidence of honeycomb weathering. The surface of the hard cap is in places irregular due to the presence of stromatalites. The rock effervesces with the addition of dilute HCl acid. In general the rock is poorly jointed.

It is thought that the rock formed in slightly hypersaline lagoonal conditions, as there are no signs of normal regular marine fossils. A forest may have existed on the edge of the lagoon.

Dirt Bed

This is a layer of ancient rendzina (limestone-based) soil that has been preserved in the Purbeck sequence. It also reacts with acid so it must contain calcite. It is matrix supported and poorly sorted with fine grains and matrix. The layer of rendzina has a variable thickness, on average 12cm. The clasts within the bed are limestone, and range in size from 5mm- 5Omm and are mostly angular. The matrix is dark grey while the clasts are dull yellow. Thus it can be said that the dirt bed is a conglomerate.

The fossil soil may have formed as sea level fell and the waters of the lagoon evaporated. Thus a soil layer is able to form due to the deposition of sediment by rivers flowing into the area. Vegetation eventually colonised the soil aiding its development.

Soft Cap

This is a very fine grained, none crystalline rock, which has salt crystals in cracks along lines of weakness. It reacts with HCI and is dark grey with a green tinge to it. The rock is well jointed with major sets trending in a NE-SW direction. On the surface of the rock, there are some light patches, which might have been caused by honeycomb weathering. The rock has no laminations and little evidence of bedding. The main compression of the rock that produces its joints comes from the south.

Broken Beds

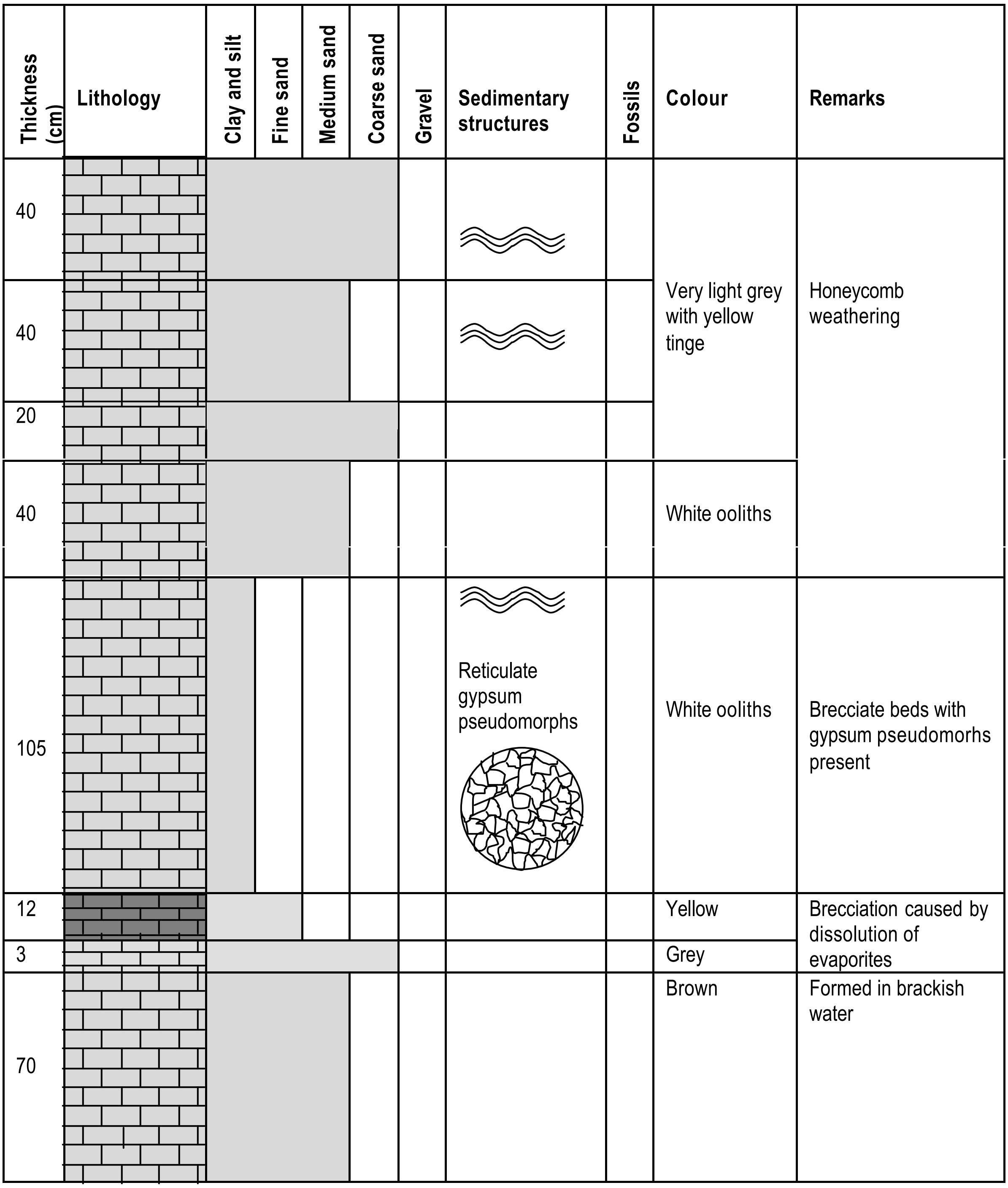
These are dull white in colour, react with acid and have a medium to coarse grain size. Within the rock are ooliths and halite pseudomorphs which have a cuboid shape and on average are 4mm in length. The beds are around 40cm thick and again show honeycomb weathering. There are also ripple marks present in the rock and weathered out ostracod shells. A thin layer of thinly laminated yellow rock with an average thickness of 12cm is also present. The layer is composed of a mixture of limestone and sandstone, with ooliths also present.

At one metre up from the base of the broken beds there is a layer of brecciation. This is caused by the solution of the gypsum present in the rock allowing the rock above to drop down, thus producing a layer of *broken* rock.

Some gypsum pseudomorphs were present in the broken beds. These are no more than 2cm in length, circular in shape and probably formed in a lagoonal environment, sealed off from the sea. The water within the lagoon soon became hypersaline and evaporation led to the precipitation gypsum and halite respectively.

Below is a neat copy of the graphic log for part of the Purbeck Beds, which I produced in the field at SY821797.

The original was drawn to scale, and was followed by further a graphic log for the Wealden Beds, plus a key.



Thickness (cm)	Lithology	Clay and silt	Fine sand	Medium sand	Coarse sand	Gravel	Sedimentary structures	Fossils	Colour	Remarks
40	▦	▨	▨	▨	▨		≋		Very light grey with yellow tinge	Honeycomb weathering
40	▦	▨	▨	▨			≋			
20	▦	▨	▨	▨	▨					
40	▦	▨	▨	▨					White ooliths	
105	▦	▨					≋ Reticulate gypsum pseudomorphs		White ooliths	Brecciate beds with gypsum pseudomorhs present
12	■	▨	▨						Yellow	Brecciation caused by dissolution of evaporites
3	▦	▨	▨	▨	▨				Grey	
70	▦	▨	▨	▨					Brown	Formed in brackish water

Wealden Clay

This was studied at SY825799, four hundred meters east of the path leading down to the sea at Lulworth Cove, Stair Hole, Durdle Door and the adjacent cliffs to the west.

This rock has a blue-grey colour and a very soft texture. It is not really a clay at all in this area: more of a gravel conglomerate, having rounded clasts larger than 2mm. The rock contains clasts of quartz and black chert and is clast supported as the larger clasts are actually being supported by smaller clasts. There is no real matrix present within the rock so the rock must have been lithified via cementation. Using the Hjulstrom diagram, if these rocks were deposited by a river, it must have had a velocity of 10 to 15m per second in order to move the clasts which averaged 2 to 6mm along the A axis.

A fluvial origin is also suggested by the presence of current bedding, inverse graded bedding and relatively poor sorting. It also included many pieces of lignite (a soft, low rank, earthy, brown-black coal, sometimes with a massive sapropelic form but more commonly composed of humic material with wood and plant remains in a finer-grained, organic groundmass.)

The lignite is limited to finer layers within the rock which must have been deposited during periods when the river was flowing more slowly or on the inside bend of a meander or even in an ox-bow lake. The Wealden beds are sometimes yellowish to brown, a colour than is probably caused by limonite, a hydrated iron ore.

Greensand.

This rock was studied at SY825799, fifty meters east of the path leading down to the sea at Lulworth cove, Stair Hole, SY823798 and Durdle Door SY805802, and the adjacent cliffs to the west, SY804803. It included shell fragments and the mineral glauconite, an iron, potassium, and aluminium silicate, which gives the rock its yellowish-greenish colour. The rock is very coarse grained, quartz rich and includes a little muscovite mica. It is very poorly consolidated and contains fossil marine bivalves and trace fossils. The palaeoenvironment must have been relatively well oxygenated with high energy levels due to currents or wave action. The Greensand is compositionally immature due to the presence of muscovite, which is usually easily broken up in a high-energy environment. Thus the older a rock the less muscovite mica there is left.

The Greensand is quite thickly bedded but has very distinct layers within it, which vary in colour between greenish yellow to strong yellow, reflecting slight differences in the composition of the sand. There are chert nodules present in the rock. They are not flint because they do not have a conchoidal fracture. The nodules are on average 50cm by 65cm. There is also some calcite cement present in the Greensand.

At the boundary between the Greensand and the Chalk there are large clasts of calcite. Technically the boundary is an unconformity, yet the time gap was very short, so a better description of it would be a hiatus. Evidence of a short time gap is seen by the fact that the large clasts of greensand, have not been weathered or eroded much. Neither has the top of the Greensand itself. There is normal fault present in the Greensand, produced by extensional forces.

Chalk.

This rock was studied in the same general areas as the Greensand. There is evidence that it was deposited in a deeper marine environment in that it includes no terrestrial sediment. Within the lowermost metre of the Chalk includes phosphate nodules which formed around small pieces of bone and teeth. The chalk is approximately fourteen meters thick before the flint nodules begin to appear. A few phosphatised ammonites have been found, also suggesting a deepish marine environment. The bivalve *Inoceramus* was found indicating the precise zone within the Chalk. Thin bands of muddy looking silt are present within the chalk, which is cut by lots of minor faults. One of these which I observed is steeply dipping towards the south. A bearing was taken on the fault to pin point its exact location: 240^{o} to the hut, located at the end of the path that leads down to the cove and 166^{o} to the far tip of the "East Point."

The candidate included a field sketch showing faults in the Chalk and a rose diagram showing the orientation of joints, if any, in each of the rock units

Safety Precautions.

We took the following precautions during our field investigation:

- Care was taken while near the shore not to slip into the sea, as tides here are quite strong and thus the risk of drowning is relatively high.
- We avoided walking on slippy algae covered stones
- We wore hard hats when working close to the cliff face and avoided overhangs, as the possibility of a landslide is very high in this area.
- We did not go on the MOD land (Ministry of Defence) to see the Fossil Forest until we had checked that the firing range was not in use.
- We avoided walking too close to cliff edges which could easily crumble away.
- We wore sensible footwear with a good tread

The Dip and Strike procedure

To ensure accurate results for the dip and strike data the following procedure was followed:

1. Locate a large piece of solid exposed rock, i.e. *5* meters in length and one meter in width minimum, ensuring that it is linked to the main rock structure, and not just a loose piece of rock.
2. Place a hard book of some sort onto the surface of the rock that is relatively flat.
3. Move the housing of the compass-clinometer around so that east "E" is in the following position on the compass.
4. Hold the clinometer on its side edge on the piece of card, and then move it around until the arrow in the centre is pointing to exactly "0" on the inside of the housing of the compass. Draw a line on the card along the edge of the compass that is in contact with the card. This line is called the strike line. At this point you measure the angle of the strike by placing the compass flat on the card with the left side lined up with the strike line. Then you simply read off the angle at which the clinometer points to. Then record the strike angle.

The candidate included two diagrams here to show the process

5. At a right angle to this line draw a short line, making sure to draw this line on the side of the strike line that is going down, the hill. Then place the clinometer onto the piece of card again with one of the longer sides running along the strike line. Then lift the other of the longer sides of the clinometer off the card, making sure to keep the other side in contact with the card. Lift the side up until the clinometer is level then stop. At this point you turn the housing of compass around until the red needle arrow is in the red arrow on the base of the housing, then read off the angle of dip from the housing of the compass. At this point you should record the dip angle.

Method used for gathering field data

At each site that we came to we followed the following procedure:

1. Locate the site precisely on the base map. Then place a small dot in pencil on the map showing your location. Next to this dot place the site number with a clear ring around it.
2. Orientate the map to the direction of north. Mark the direction of north on the map, with a label arrow.
3. Observe the rock at the site.
4. Execute the dip and strike procedure on the pieces of exposed rock. Then record the dip and strike onto your map in the following way. Using a pencil and the straight edge of the compass mark on the strike line, this line should only be about *0.5* cm long. Then mark on the dip, this line is drawn with a ruler and pencil at 90 to the strike line, this line should be about 2-3mm long. Remember to place the line of dip on the correct side of the strike line. At the end of the dip line the angle of dip should be written clearly. Do not place a degrees symbol on the end of this figure.
5. Decide on the rock type of the site. Then using a coloured crayon to represent that particular rock type, shade along the strike line, of the dip and strike symbol, remembering to draw up a key.
6. Draw a field sketch of the rock exposure and any interesting fossils and sedimentary structures.
7. Describe the rock type located at each particular site, using the following checklist as a guide of what to include in the description.
    - rock type
    - colour
    - grain size
    - sorting
    - whether the rock is matrix or clast supported.
    - orientation or alignment of the grains in the rock.
    - the composition of the rock, i.e. what minerals and other sediments are contained within the rock.
    - sedimentary structures.
    - fossils present.

Results.

The following tables summarise the dip and strike readings at various points.

Grid Ref / Location	Mean Dip	Direction	Rock Type	Sample Size
SY821797	29	NE	Soft Cap	1
	42	N	Hard Cap	4
SY825798	53	N	Hard Cap	5
East of Stair Hole	68	N	Undifferentiated	1
	26	NE	Normal Fault	1
	74	NW	Normal Fault	1
Durdle Door	71	N	Undifferentiated	4
Lulworth Cove 50m east of path	76	N	Greensand	1
Durdle Door	75	S (inverted)	Greensand	6
West side of Stair Hole	82	S (inverted)	Purbeck Beds	1

A Description of the overall Geological Structure of the Lulworth Cove Region.

The sequence of rocks found in the Lulworth cove area has been folded into a monocline, the vertical limb of which runs in an east-west direction, for 80 km, from Lulworth to the Isle of White. This vertical limb runs along the length of a fracture formed in the underlying basement rock 300 million years ago, due to earth movements caused by processes of mountain building taking place. At Lulworth the sea has eroded through the monocline, from the south, exposing the Portland limestones in the most southerly cliffs.

The bay is cut into Purbeck, Wealden and Greensand strata and backed at its northern end by the chalk. It is evident that a fault runs through the middle of Lulworth Cove due to the fact that the dip of the beds of rock differs significantly on the east and west side of the cove. This is evident from the dip and strike readings that were taken, on either side of the cove and from the geological map of the area which shows that outcrop widths are much thinner on the west side of the cove, due to steeper dips. The sudden change in dip angle strongly suggests a fault running N-S through the cove.

Stair Hole is quite simply the immature version of Lulworth cove. The ‘Lulworth Crumple’ located in the cliffs at Stair Hole, formed due to north-south compression during the Alpine orogeny, 30 million years ago, which was caused by the collision of the African an European plates in the Mediterranean. As a result the harder limestone's of the Portland Stone and the chalk, squeezed the softer layers of rock that are located between these two rock types, that is the Wealden sands, Greensand, and Purbeck beds. Thus the asymmetric folds and kinks were produced in the softer rock types, such as the Lulworth Crumple, as shown below.

Interpretation of the geological map that I completed, along with the section that I constructed.

The candidate included two geological maps of the region which he had created from the data he collected. The first showed the precise locations where observations had been made. The next showed the certain boundaries between formations, inferred boundaries and the positions of faults and folds. Both were of good quality.

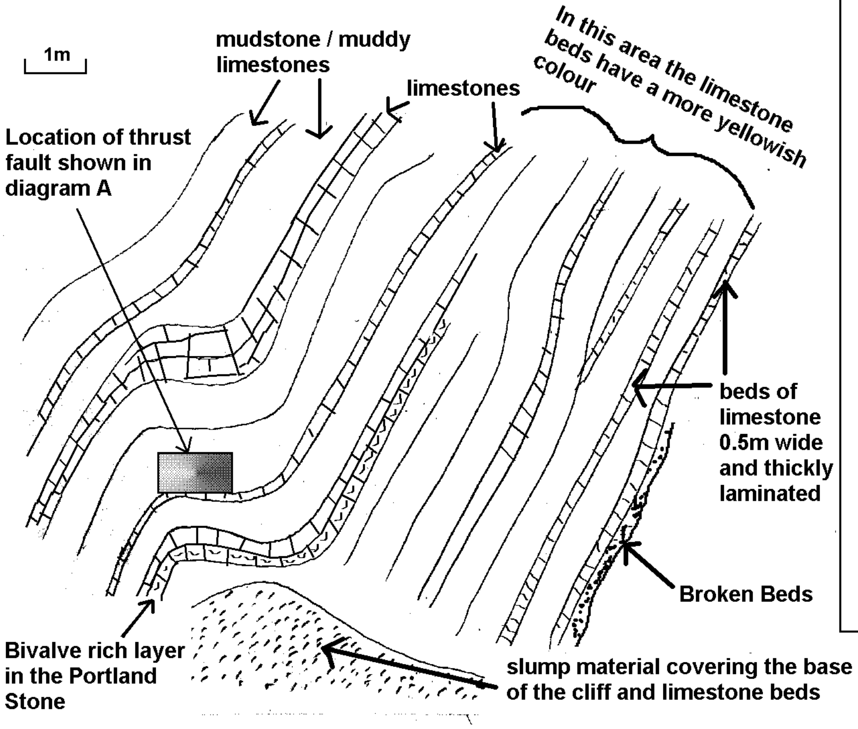
From the work recorded in the field I was able to accurately locate the boundary between the Greensand and the Chalk, and the boundary between the Purbeck beds and the Wealden clays. Where there was no exposure I inferred the location of boundaries using feature mapping, e.g. the location of the Gault Clay. I also inferred the location of a fault that runs directly through the cove.

The cross section was done on the east side of the cove where gentler dips produced wider outcrops which were easier to plot. The accuracy is enhanced as I took many dip and strike measurements out in the field and calculated averages for each formation. Looking at the dip of the beds of rock it can be seen that the dip of the beds becomes shallower as you move southwards from the Chalk to the Portland Stone. As the average dip of the inverted beds of Greensand is 74°S while that of the Portland Stone is 50°N

A good quality cross section through the map was included to show the overall structure of the region.

Grid Reference: SY825798
Date: 31-3-99
Location: West Side of Stair Hole
Lithology: Portland Stone (limestone)
Age: Upper Jurassic

Field sketch showing the folding and faulting present in the Portland Sone at Stair Hole



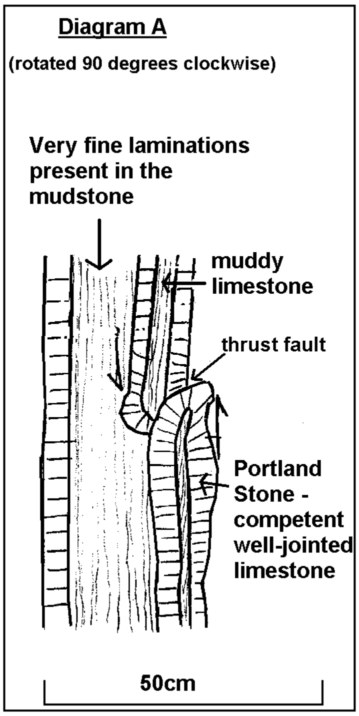


Diagram A

(rotated 90 degrees clockwise)

Another field sketch of similar quality was included to show the features on the east side of Stair Hole

The geological history for the area

First the Portland Stone was deposited in a shallow marine environment. Uplift then produced lagoonal and terrestrial conditions while the Purbeck formation was deposited, i.e. Hard cap, then the Dirt Bed, the Soft Cap and the Broken beds. During this time forests and soils existed, some of which are preserved. The Wealden Clay was then deposited in a fluvial environment and was followed by the Gault (which I did not see exposed). The Greensand followed, being laid down in a shallow shelf sea and after a very short period of uplift and erosion a deeper sea developed resulting in the deposition of the Chalk. The climate throughout this period was probably sub-tropical. The Alpine orogeny then occurred with N-S stresses producing the monocline which runs E-W through the area, and which includes the crumpled beds of Stair Hole. A fault also occurred at about this time running N-S through Lulworth Cove

Evaluation

I believe that the data I collected for this investigation is quite accurate as I am confident using compass-clinometer, hand lens, base map, grain size and texture card, etc. Taking several dip readings and finding and average also minimised the chances of including erroneous dip readings, however, there were some locations where this was not possible. The exposure in the area is quite good so it was possible to get a good look at most of the strata. However, some locations had to be avoided because they were too dangerous and in other locations, rock falls had covered up strata near the bottom of the cliff.

One definite source of error comes when you have to plot the positions of the geological boundaries inland from the coast. In these areas there is no exposure and I had to use feature mapping, which is not always reliable and includes the making of assumptions which cannot guarantee to be correct.

To overcome this problem, we would need to spend more time to find stream cuttings where the bedrock was exposed. With adequate funding, boreholes could be sunk to confirm the presence of particular strata. Geophysical surveys such as resistivity, magnetic, gravity and seismic would also help, but for such a detailed survey a lot of money would be needed and there would have to be a special incentive to spend it, e.g. investigating the possibility of oil reserves. A seismic survey would certainly help to prove if there is a fault in Lulworth Cove.

However, despite the lack of these facilities, the landform features in this area are quite distinct and relate very well to the particular rock types, so I still think my map is pretty accurate.

If I had had more time, I would have been able to collect more data from a wider area. This would definitely improve the reliability of the data and any conclusions drawn from it. To find the detailed mineral compositions of the strata and the texture, thin sections could be used, but this was not possible for us. In general, however, I think my project has worked very well.

Moderator's assessment of the graphic logging exercise

Skill **I**

The candidate's work clearly justifies the top mark. Staff comments on the work support the idea that the candidate made abundant accurate observations and measurements and showed competence and confidence in using the necessary equipment. The work satisfies all the grade descriptors up to and including 7b.

Suggested Mark: 7

Skill **A**

All aspects of this skill are covered thoroughly. The candidate uses knowledge and understanding from several parts of the specification (especially Modules 2831, 2832 and 2835), Clearly meeting the advanced level coursework requirements for descriptors up to 7b. As the work is also very well structured and well written with abundant use of appropriate geological terminology, it probably justifies top marks.

Suggested Mark: 8

Exemplar Investigation 9

A laboratory-based investigation into cooling rates and crystal size

A laboratory-based investigation into cooling rates and crystal size (Skills P and E).

(Based on Module 3835)

Instructions to candidates

Skill P: Planning
Skill E: Evaluation

Your task is to investigate the crystal size in igneous rocks. Read carefully the elements and descriptors of Skills P, I, A & E using the sheets provided before making your plan. You should also read your class notes and the sections on the crystallisation and grain size in igneous rocks in your textbook. You must develop a complete plan before you will be allowed to start your experiment. In you plan you should:

1. Show evidence that you have understood the geological theories which attempt to explain crystal size in igneous rocks, and considered how they might be used to help to develop the plan [Sub-skill P 4]

2. State clearly which aspects of crystallisation you aim to investigate explain their geological significance and make a prediction of the results or set an hypothesis for testing. [Sub-skills P 1 and 2]

3. Identify the key factors which you aim to control, measure, observe and record. [Sub-skill P 3]

4. Identify the equipment which you intend to use to fulfil this and explain the procedures you will adopt to ensure the accuracy and reliability of the data collected. [Sub-skills P 2 and 5]

5. Decide how many observation and measurements might be appropriate. [Sub-skill P 3]

6. Explain the measures which will need to be followed to ensure safety [Sub-skill P 5]

7. Produce a detailed itemised, sequential list of tasks and clearly justify the strategy and methods you are proposing [Sub-skills P 2 and 4]

8. Explain clearly how the information will be recorded, processed and analysed.

9. Include a section explaining how the processed data and the plan itself will be evaluated once the investigation is completed.

10. Use appropriate geological terminology and ensure that your spelling, punctuation and grammar are correct. [Sub-skill P 6]

Once you have carried out your plan you should display and give a brief explanation of the results. You should then carry out a full evaluation of the experiment in which you:

11. Identify and explain any unexpected or anomalous observations or results.

12. Assess the accuracy of the data.

13. Identify and assess the limitations of the specific techniques you have chosen to use and explain how these may have contributed to errors.

14. Assess and strengths and weaknesses of the overall strategy/plan and the validity of the conclusions made as a result of it.

15. Suggest and justify how the techniques used and strategy followed might be improved.

A laboratory-based investigation into cooling rates and crystal size

This exercise was attempted by a candidate who had completed Module 2835. The class teacher had already discussed with the class the requirements of Skill P and had gone through a 'worked exemplar' for them on another topic, which they were not allowed to repeat.

An investigation into the relationship between crystal size and cooling rate

Aim:

The main aim is to investigate the size of crystals forming in solutions of Salol in relationship to the length of time that it takes for crystallisation to be completed under a variety of temperature controlled circumstances.

Theory:

Igneous rocks are observed to have a wide variety of crystal sizes. It is clear that lavas erupting at the surface usual only have small crystals. One theory for this is that because temperatures in the air and on the ground are so much less than that of the lava it cools down much more quickly than it would do underground. There is therefore not enough time for big crystals to grow. Some lavas, however, are observed to have bigger crystals (phenocrysts) surrounded by a finer groundmass - it is likely that these big crystals formed while the lava was still in its magma chamber. Rocks crystallising underground have bigger grain sizes, with the precise crystal size depending on the size of the intrusion, the depth beneath the surface and the temperature of the country rocks - thus the bigger the intrusion, the deeper in the crust it is and the hotter the surrounding rocks, the longer the cooling process will take and the larger the crystals will be. This is strongly suggested by the rocks gabbro, dolerite and basalt all of which have the same mineral and chemical composition but very different grain sizes and textures. The theory that crystal size is proportional to cooling time is based largely on secondary evidence and analysis of thin sections - it is physically impossible to observe crystallisation of magma taking place and even with lava the high temperatures would mean that we could only look from a distance and observation of actual *crystallisation* would not be possible.

This investigation attempts to simulate the crystallisation of lava in the laboratory using salol, so that the relationship between crystal size and cooling rate can actually be observed, to test the **hypothesis** that 'Crystal size is directly proportional to the length of time that it takes for crystallisation to be completed.'

Apparatus: rule, boiling tube, test tube holder, tongs, stop-clock, gauze, thermometer, bunsen burner, refrigerator, microscope, 3 microscope slides, beaker, tripod, pipette, salol crystals.

Safety considerations: Salol crystals were chosen because their low melting point and non-toxic nature, both of which enhance the safety of the experiment. Standard laboratory safety procedures were followed throughout.

Method *(The candidate provided labelled diagrams to show each stage of the process outlined below)*

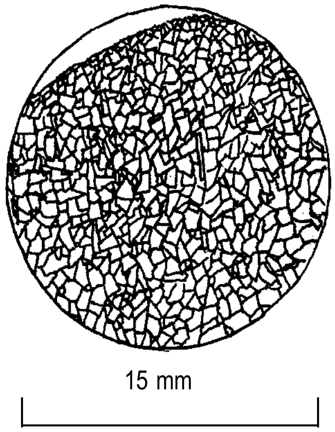
1. Using the rule, fill the boiling tube to a depth of 2 cm with salol crystals and insert the thermometer.
2. Heat boiling tube in a beaker containing water whilst starting the stop-clock.
3. Record the time and temperature at which the first salol crystals melt, when 50% of the crystals have melted and when all the crystals have melted.
4. Place the microscope slide on the microscope turntable
5. Using a pipette apply a few drops to the microscope slide.
6. Record the time taken for: -
    (a) the first crystals to form
    (b) 50% of the liquid to become solid
    (c) 100% of the melt to become solid
7. Move the slide on the microscope so that the cross-wires are over the centre of the mass of crystals.
8. Place a rule next to the crystals so that it can be seen in the Microscope.
9. Select the 10 crystals nearest to the cross-wire intersection and measure them.
10. Calculate and record the average minimum diameter for each crystal.

This procedure should be repeated three times - firstly with a slide taken from a freezer and chilled to –5°C; secondly with a slide at room temperature (20°C) and finally with a slide warmed up to 78°C (the temperature by which all the salol crystals should melt). Tongs should be used to transport the coldest and warmest slides to the microscope turntable to avoid warming them or cooling them by skin contact. Transport should be as fast as possible.

Results:

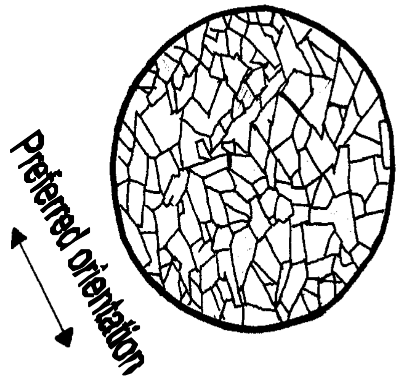
This procedure was trialed in the school chemistry lab and the numeric results are shown in the table below as well as sketches to show the grain size and texture of the crystals on the three slides.

SLIDE 1: Granular texture; mean crystal size 0.8 mm; random orientation.
Very fine crystals at the edge of the sample

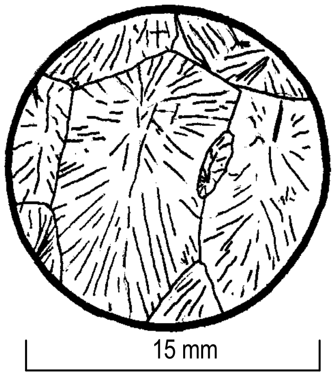


Cooling rate and crystal size	Slide 1 (-5 Celcius)	Slide 2 (20 Celcius)	Slide 3 (78 Celcius)
Time taken for the first crystals to form (seconds)	0.2	2	521
Time taken for 50% of the melt to crystallise (seconds)	0.9	10	608
Time taken for complete crystallisation (seconds)	1.0	44	819
Mean diameter of crystals (mm)	0.8	1.6	8.9

SLIDE 2: Granular texture; mean crystal size 1.6 mm; slight evidence of parallel alignment



SLIDE 3: Granular texture; mean crystal size 8.9 mm; slight evidence of parallel alignment.



With slide 1 the crystallisation process was very quick and there was very little variation in the crystal sizes (maximum 1.6 mm and minimum 0.2mm). The crystals at the edge of the mass were particularly fine, suggesting that these formed fastest of all because they were not surrounded by warm salol melt on all sides. The speed of crystallisation on this slide was so fast that the melt did not have time to spread across the slide, thus the crystals were confined to a smaller area than with the other two slides, but presented a thicker layer.

The melt on Slide 2 crystallised much more slowly and spread further across the slide, as the melt retained lower viscosity for a longer period of time. The first crystals started to form after 2 seconds around air bubbles in the liquid and at the edge of the melt. An equigranular texture resulted but with some evidence of a preferred orientation. This may be due to the spreading of the melt during crystallisation, or perhaps, the slide was not absolutely horizontal causing the liquid to flow a little. Another interesting feature of Slide 2 was that there was a bigger range of crystal sizes, going from as little as 0.4 mm to 3.2 mm.

The crystals took longest to form on Slide 3. There was also the greatest difference between their sizes (1.6 to 11.0 mm). Only five crystals formed. The smallest crystal formed last in between the larger earlier crystals.

Conclusion:

The results of the experiment do support the hypothesis that 'Crystal size is directly proportional to the length of time that it takes for crystallisation to be completed.'

Evaluation of experiment and modification of plan:

While the experiment generally worked well, there were a few problems:-

- Putting droplets of salol melt onto the first two slides went according to plan, but with the third slide being heated to 78°C the first attempt to produce any crystals failed completely - even after an hour there were none. It became apparent that this was due to the heat from the light source for the microscope. Eventually a different microscope, with a remote light source and a mirror below the slide, was used to solve the problem.

- Despite attempts to control the temperatures of the slides there is little doubt that their temperatures were subject to change between the time that their temperature were measured and the time that the salol was applied.

- The mean crystal width for Slide 3 is only based on five crystals in total. The means for slides 1 and 2 are based on double the sample size. One way to avoid this would be to use larger non-standard microscope slides and perhaps 4 drops of salol melt.

- Measuring the time of onset of crystallisation, 50% and 100% completion was very difficult for slide 1 and the figures may be inaccurate. It may have been better to repeat the procedure 3 times, assessing only one of these times on each occasion.

- While testing three slides at different temperatures does prove that crystal size is proportional to the length of time they took to form. It provides insufficient evidence to show whether this relationship is linear. With further slides heated to standard temperatures, e.g. 10, 20, 30, 40°C , etc., a better understanding of the relationship between cooling rate and crystal size.

- While the results of the experiment support the hypothesis, the volume of evidence is small and limited to one substance. To confirm the findings a similar experiment could be carried out with a different substance such as stearic acid.

- A final problem was the difficulty in applying droplets of melted salol of exactly the same size.

Bibliography: the candidate listed two texts, plus her class notes.

Moderator's assessment of the crystallisation work

Skill **P**

Candidate A defines the question with clear reference to scientific knowledge and understanding, identifying all the key factors to control and account for. She uses specialist vocabulary in an appropriate fashion and her spelling, punctuation and grammar are excellent throughout. She develops an effective strategy and makes a suitable choice of equipment. It is clear from her section on theory that she has consulted secondary sources prior to developing the plan. She establishes good safety procedures (e.g. using salol - a harmless substance) and is careful to minimise sources of error (e.g. using tongs to move the slides), and achieve maximum accuracy (e.g. use of rule, electronic stop clock).

Suggested mark: 8

Skill **E**

Candidate A reaches all the requirements for the top mark for this skill. There is a clear recognition of potential sources of error (e.g. maintaining slide temperatures) and limitations in the procedures followed and the data resulting from them (e.g. the limited number of crystals in slide 3). She makes good suggestions about how the investigation could be improved and justifies them by scientific argument.

Suggested mark: 7

Exemplar Investigation 10

An investigation into the origin of Triassic sediments at Lochester

An investigation into the origin of Triassic sediments at Lochester (Skills P and I)

(Based on Module 2835)

Instructions to candidates

Skill **P**: Planning
Skill **I**: Implementing

This exercise was attempted by a candidate who had completed Modules 2832 and 2835. The class teacher had already discussed with the class the requirements of Skills **P** and **I** and had gone through a 'worked exemplar' for them on another topic, which they were not allowed to repeat. Instruction sheets similar to that shown for the Skill **P** extension to the Fox Bay exercise were also provided.

An investigation into the origin of Triassic sediments at Lochester

*N.B. Some of the material produced by this candidate has been removed or summarised for the sake of brevity, but only where it is not directly relevant to the assessment of Skills **P** & **I**.*

Aim

The aim of this investigation is to test the hypothesis that 'the sandstones and conglomerates at Lochester Country Park were deposited as part of an alluvial fan in semi-arid conditions.'

Theory

Sandstones and conglomerates can be deposited in a wide variety of environments but a close study of their composition, textures and sedimentary structures should give us a clue of their precise origin. The rocks at Lochester are shown as of Triassic age on the BGS map. It is known that Britain was part of a super-continent at this time, cut-off from rain bearing winds. In such conditions today alluvial fans are common features where mountains run down to meet the plains. Their deposits have a number of key features:-

- Fan shaped depositional areas (sometimes as large as 40kms across)
- Decreasing grain size away from the mountains
- Lack of fossil remains
- Sinuous and often braided channel systems
- Haematite rich matrix
- Current bedding of sands
- Imbrication of elongate and platy pebbles
- Rapid lateral facies variation

At Lochester a series of abandoned sand and gravel quarries have been converted into a country park with open access to the public. Exposures of sandstone and conglomerate are common and as the dip of the rocks is close to horizontal it should be possible to plot the continuity of the strata (or the lack of it) from one quarry to the next. Field data will be collected from each quarry to assess the extent to which the above features can be found. A special effort will involve investigating the form of the channel deposits. A map will be produced to show the likely course of channels.

Apparatus

The following material will be needed: base map of the quarries, tape, compass, clinometer, camera, field notebook and sketch pad, graphic logging sheets, hand lens.

Method

Each of the quarries shown on the base map should be examined and the following procedures carried out:-

1. Identify the main rock units visible in the quarry, checking each wall to see if there is any variation. If there is a variation then the following tasks will need to be repeated for different locations within the quarry, which should be clearly marked on the base map and referred to in the field notes.

2. For a typical vertical section complete a graphic log to show the changes in rock types, grain size, textures, sedimentary structures, fossil content, etc. A photograph to show the main features should be taken or a labelled field sketch completed.

3. For each rock unit in the log (as far as possible and without climbing the quarry face) collect data on the current bedding to enable the calculation of palaeocurrent directions.

4. For all exposures of conglomerate the following data will be collected:-

- **Grain Size**: mean size of phenoclasts and matrix; maximum phenoclast size
- **Texture**: degree of sorting; proportion of phenoclasts to matrix; roundness and sphericity of phenoclasts
- **Composition**: of phenoclasts and matrix
- **Sedimentary Structures**: bedding - the nature of their upper and lower boundaries, maximum and minimum thickness, lateral extent where lensing out occurs; jointing; current bedding; graded bedding; imbrication, etc.
- **Fossil Content**: if any.

Due care should be taken to ensure the safety of self and others at all times. This includes:-

- avoiding unstable cliff edges and overhangs
- wearing a protective helmet
- wearing goggles when using a geological hammer
- ensuring that nobody else is within range of chipped rock fragments when using the hammer
- wearing good walking boots with a thick tread to avoid slipping on rock surfaces and steep slopes
- if possible, carrying out the research with another person present

Data processing and analysis

When all the data has been collected an attempt will be made to produce:-

1. a simple stratigraphic column for the strata
2. a map showing the locations of conglomerates and their likely continuity, illustrating the form of the channels in this area.

To create the stratigraphic column, the graphic logs from each exposure will be laid side by side and an attempt to identify 'similar' beds made. Where conglomerates are present the full rock descriptions will be used to make sure that units are matched only with good supporting evidence.

Results

Hillfield Quarry

Identify the main rock units visible in the quarry, checking each wall to see if there is any variation. If there is a variation then the following tasks will need to be repeated for different locations within the quarry, which should be clearly marked on the base map and referred to in the field notes.

There were two rock types in this quarry. The first was a medium grained yellow sandstone. The beds went from 15cm thick up to about 70cm. The texture was rough and the grains sand sized (mostly around 1mm). There were signs of cross bedding with the lines going down to the NE so the current must have come from the SW. I took a several readings from the same bed at different parts of the quarry and they all showed the same direction. There were no fossils present in the rock. The dip was SE.

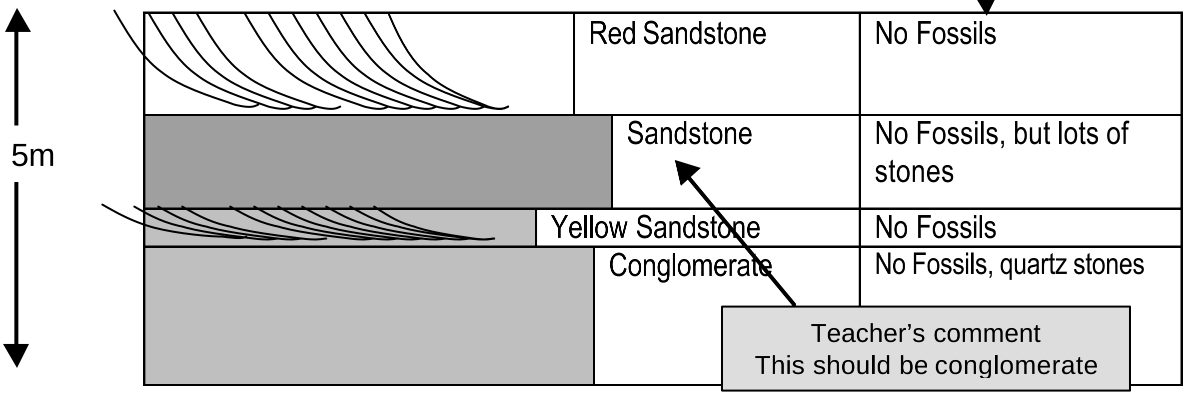
The other rock was a conglomerate. This was present in the northern corner of the quarry and at its southern end. It had lots of rounded stones in it which went from about 1cm to as much as 15cm. The stones looked white and crystalline. They were also hard and could not be scratched with a knife, so they must be quartz. There were also some black and grey phenocrysts which might have been basalt and limestone. The beds of conglomerate came and went from place to place. It was very hard to find a place to take a dip reading but the rock seemed to dip along with the sandstone so that is to the SE.

The Gulch

This quarry also had the same rocks in it. The graphic log, below, shows how they looked.

Teacher's comment

Very little detail in this log!

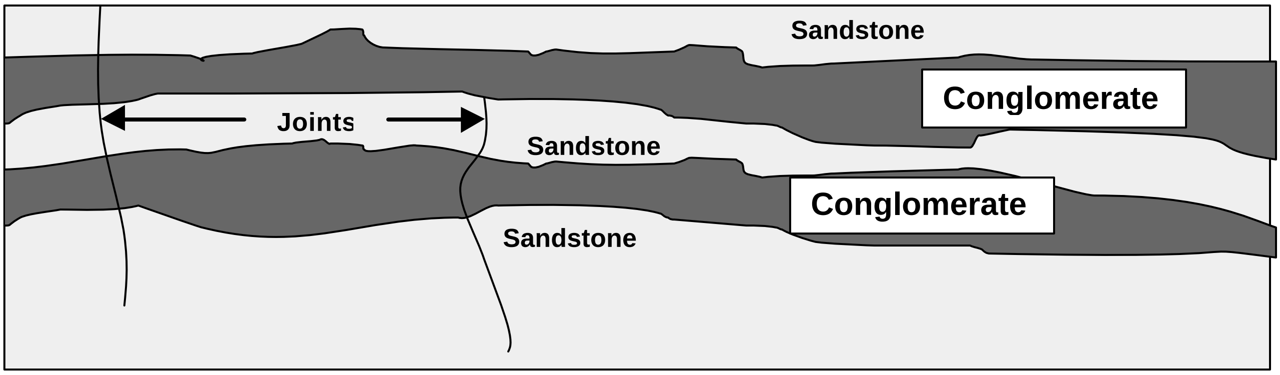


Teacher's comment
This should be conglomerate

The conglomerates had beds which changed thickness. In some places there were lens shaped deposits which suggest river channels, in other places they died out and were replaced by sandstone. Even the sandstones had some pebbles in. The pebbles were very rounded therefore they must have been bashed about by rivers or it might have been a flood. The red colour must mean a desert situation with lots of iron around. If it was a desert then this explains why there are no fossils, because nothing would live there!

West Quarry

The walls of most of this quarry had been collapsed by the authorities to stop people falling in, and grass had been planted so it was not easy to see the rocks. At the northern end though there were three bands of pebbles. They were rounded and there were lots of white pebbles just like at Hillfield. The beds varied between zero and 2 metres thick and the pebbles had a smooth texture and were well sorted. I also saw some pebbles which look like they might have been granite. These had some feldspar and silvery mica present. The rocks were dipping at 5°. The field sketch below shows the rock units present.

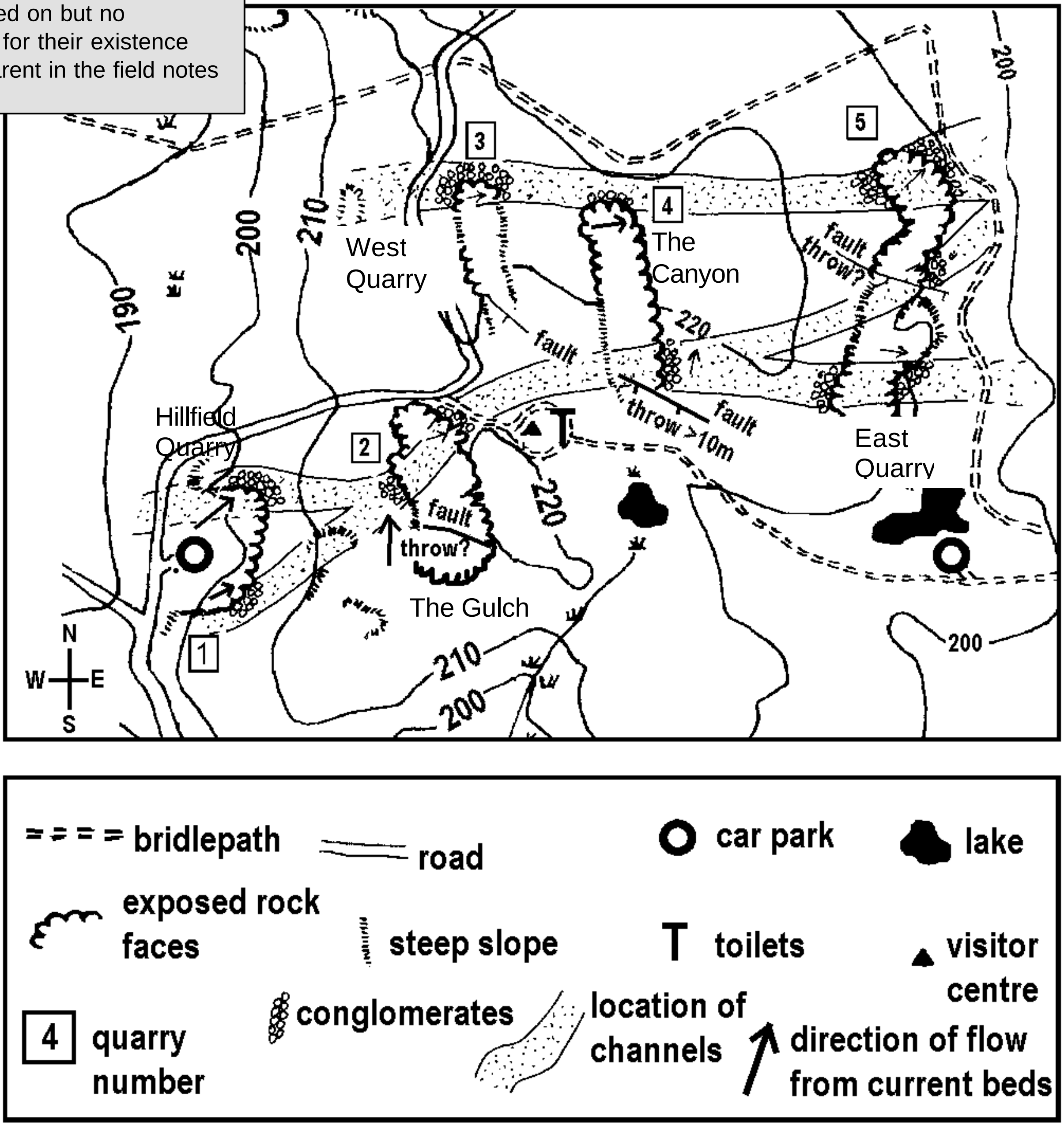


Teacher's Comment

No scale or title and no attempt to show the internal structure of the beds

The other quarries were covered by the candidate in much the same way. No attempt to create a stratigraphic column.

Teacher's Comment
No attempt to plot on dip angles and amounts. Faults are marked on but no evidence for their existence was apparent in the field notes



Conclusion and evaluation

The graphic logs, rock descriptions, location and form of channel deposits support the hypothesis that 'the sandstones and conglomerates at Lochester Country Park were deposited as part of an alluvial fan in semi arid conditions.' The sediments lacked fossils, were current bedded with a haematite rich matrix and sinuous channel deposits. The absence of fossils means that these rocks could not have been laid down in the sea. However, there were some problems associated with the investigation:-

- Some of the features I expected to find were not present, e.g. very few of the pebbles were elongate so there was no evidence of imbricate structure.

- Many of the quarry slopes had become overgrown with gorse and trees making access very difficult.

- It was often difficult to get more than one measurement of current bed dips, so the palaeocurrent directions may not be very accurate.

- There were several places where vertical faults brought rocks of totally different types into contact. It was not easy to work out which way the faults had moved.

Another way of trying to prove that these rocks are semi-arid fan deposits might be by crushing the sandstone and carrying out sieving and seeing if the grain size distribution matches up with that for known fan deposits. This should be quite easy as the rock is quite friable. The coefficients of sorting and skewness could be calculated and compared to sediments from a variety of origins. An attempt could also be made to work out where the phenoclasts came from. Looking at other local outcrops of the Triassic sediments and other rocks may help to work out which way the faults have moved.

Moderator's assessment of the Lochester field mapping exercise

Skill **P**

The candidate identifies the problem clearly enough and the types of data that need to be collected for its resolution. He also explains the theoretical background quite well but is a little unrealistic in picking features of alluvial fan deposits which could be tested in a limited area such as that covered by the quarries. Most of his techniques are basically sound but he required some staff help to understand the ways that the graphic logs could be used once they had been created. He shows good awareness of the need to take account of safety and to adopt standardised recording methods. Although the plan itself is probably over-ambitious and rather flawed in places, it still meets all the criteria for the top mark. We would not expect an A Level candidate to have the level of geological knowledge and understanding to draw up a perfect plan for this investigation. It is evident from the candidate's notes, in the theory section of the submission, that a variety of sources were used to help develop the plan. There are also clear attempts to justify the plan incorporated in the theory and methods sections.

Suggested mark: 8

Skill **I**

A difficult piece of work to assess. The plan was quite impressive but the candidate does not seem to have carried out all aspects of it. The data is poorly structured and there are some important omissions, e.g. dip directions with no angles (and vice-versa) and poor use of appropriate geological terminology. Some of the measurements are precise but others are not. There is a great deal of data which the candidate failed to collect. He clearly achieves the descriptors for 1a, 1b and possibly 3a, but he fails to match up to the demands of 3b. Therefore the maximum mark he can achieve is 2, which is a regrettable after such a good plan was created. It is hard to believe that the Skill I work was carried out be the same candidate!

Suggested mark: 2