EARTH SCIENCE OUT-OF-DOORS - A DISCUSSION OF TEACHING STRATEGIES FOR USE IN THE FIELD BASED UPON EXPERIENCES OF THE TRIASSIC ROCKS OF THE NORTHWEST PART OF ALDERLEY EDGE, CHESHIRE

This account is based upon interactive discussions in the field which took place at the Earth Science Teachers Association Course and Conference, 15-17 September 1989, notably on the afternoon of Saturday, 16th September.

A. Introduction

The purpose of these discussions in the field are five-fold:

1. To introduce science teachers to a geological environment which provides abundant opportunities for students to develop the skills, methodologies and attitudes espoused by GCSE science courses (DES 1985) and the National Science Curriculum (DES 1989 Attainment Target 1: Exploration of Science).

2. To discuss the principles of selecting a route across such an area and of choosing a range of teaching activities which are suited to investigations by 13-16 and 16-19 year old students.

3. To update teachers with respect to the Triassic succession at Alderley Edge: its age, the sedimentology, the structural context and the archaeology, nature and origin of its mineralisation (Thompson 1970, a, b, c; Naylor et al. 1989).

4. To introduce members to the technical, environmental, social and other applied aspects of science; to problems of water supply; to the mining history and ore treatement processes of the area (Carlon 1979, Warrington 1981) and the problems of access and conservation which the owners, the National Trust, and the leasees of the mines, the Derbyshire Caving Club, have to face (Dibben 1989; Vincent 1986).

5. To provide visits to locations and experiences which will allow students to fulfil the course requirements of the Northern Examining Board (NEA) and the Midland Examining Group (MEG) geology syllabus for GCSE and the Advanced Level geology syllabus requirements of the Joint Matriculation Board (JMB) for GCE.

The area in general

Alderley Edge trends west to east for 3 km and lies only 20 km south of the centre of Manchester (Fig.1). It comprises a complex escarpment and dip slope formed of rocks of the Lower Triassic Sherwood Sandstone Group (SSG) reaching up to 200m high (660 ft), some 100m above the general level of the surrounding plain which is floored by the overlying Mercia Mudstone Group

(MMG) (Middle and Upper Triassic) surmounted by Devensian and Holocene superficial sands, gravels and tills.

The structure

The Edge is the most northly expression of a horst which is bounded to east and west by two north-south major normal faults, both of which throw over 200m (750 ft) - the Alderley Fault to the west and the Kirkleyditch Fault to the east (see Fig. 2), the latter being antithetic to the general sense of movement of the faults in the Red Rock Fault Zone which forms the eastern margin of the Permo-Triassic extensional basin (Chadwick in Whittaker 1985). Within the horst there are smaller north-south faults together with others which trend WNW-ESE and the red sandstones which are adjacent to both sets display appreciable mineralisation.

The mineralisation

The mineralisation is largely of the elements Cu and Pb, which originally expressed themselves as sulphides, but are now often in hydrated and oxygenated form. Minor amounts of Mn (with Co and Ni), Zn, V, As, Sb, Ag and Au are present. The association of these elements is typical of red-bed copper deposits all over the world (Stanton 1972). The solutions from which the metals have precipitated may have been generated by the dissolution of suitable elements from the darkest shales of the underlying carboniferous rocks, but are more likely from the breakdown of suitable sand and silt grains in the Sherwood Sandstone and Mercia Mudstone Groups; the sulphur isotopes in the sulphide ores and barite gangue minerals indicate that they originated from marine Triassic seawaters comparable to those which gave rise to the Northwich and Wilkesley Halite Formations of the MMG. The fluid inclusions in the calcite gangue minerals suggest that the final mineralising events may have talen place at temperatures as low as 59-80°C (Naylor et al. 1989). The solutions are believed to have uprisen along basin-margin faults by seismic pumping mechanisms (Sibson et al. 1975) and chose to crystallise in the abundant 30% pore space of the adjacent fluvial and aeolian sandstones of the SSG which lie immediately below the impervious cover of the MMG. Local mineralisation traps are often apparent for 100m below the main seal, so that West Mine, Wood Mine, Engine Vein Mine and the Stormy Point Mines are developed in successively lower beds of the Helsby and Wilmslow Sandstone Formations (Fig.3). The Alderley Edge Mines are but one of several comparable red bed copper deposits in the Cheshire basin (Fig.1).

The archaeology and mining history

The history of mining in the area is reasonably documented by geologists (Carlon 1979, Warrington 1981), but not alas! by historians of science. The earliest workings are increasingly considered to go back to Bronze Age, even E arly Bronze Age times c. 3000-3500 BC, for recent work on the styles of stone hammers found on the edge and the archaeology of the stone pits at Engine Vein particularly (Gale 1986, 1988 unpublished work, University of Bradford) have tended to confirm the likelihood that prehistoric miners were at work near places now known as Engine Vein, Wood Mine, Stormy Point and Mottram Mines, an opinion offered long ago by Roeder (1901) and Roeder and Graves (1905).

Failing direct evidence that mining took place in Roman times or the Middle Ages, nothing is known for certain until the late 17th century, after the Acts of William and Mary 1688-993 had revoked the Crown Monopoly on mining. Before these Acts, any ores and mines bearing a tenor of gold or silver were largely vested in the crown and were worked only under licence. After the change in the law, many landowners permitted exploration under lease (on payment of a fee) and welcomed exploitation on agreement of a royalty (usually 1/5 at first)). This resulted in many mines being opened up in the red bed copper deposits which underlie the estates of large landowners of the Cheshire Basin. The principal leases and mines are recorded in the chart (Fig. 5; Warrington 1981) and their locations on the map(Fig.1).

At Alderley Edge the first major mining efforts took place in the 1760s when the Macclesfield Copper Company, led by Charles Roe, was activeuntil he found a better prospect in the Ordovician Sediments of Parys Mountain, Anglesey. Soon after the turn of the 19th century, an Alderley Mine Company was working copper under James Ashton from Derbyshire and they were soon joined by Mr Plowes of the Pontefract Company, who successfully worked cobalt ores for a short period. The whereabouts of their workings has only recently come to light (Johnson 1984) through the careful rescrutiny of old records (Bakewell 1811, 1813) by members ;of the Derbyshire Caving Club. The rediscovery and exploration of the Wizard's Well Cobalt Mine is certainly a major triumph for the Club and science teachers could safely recommend that their more adventurous, even troublesome, members could join it and so learn the need for self-discipline and cooperative effort.

The most important period of mining started in 1857 when James Mitchell, a Cornishman, made an agreement with Lord Stanley concerning the exploration of his Alderley estate. By 1859, the Alderley Edge Mining Company was formed and already the Wood Mine, Engine Vein, Stormy Point and West Mines were partly opened up (Fig. 6), the latter showing the immense caverns (stopes) where ores had been taken out.. This is the mine which will be visited on the Sunday afternoon of the ESTA Conference. From 1857 to 1877 the main production from the Alderley Mines was of copper ores but lead was produced at times when economic conditions became favourable e.g., by the dependent company - the Patent White Lead Co (1862-4). The equally-dependent Macclesfield Patent Sulphate of Copper Company (1862-1870) was longer-lived. In the 1920s solutions of copper sulphate were produced at Alderley and were sprayed on vines on the continent as a fungicide. The mines were briefly opened in the 20th century but without great success, the latest company being dissolved in 1927 (Carlon 1979, Warrington 1981).

Details of the theory and technology of the mineral-processing chemistry involved in extracting the metals from the ore are to be found in Carlon's book (1979) and are the subject of a display in the Manchester University Museum, Oxford Road, to which students may usefully be directed. These processes include the milling and smelting of the lead, the digesting of the copper ores in hydrochloric acid and theprecipitation of copper from the resultant liquid by throwing in scrap iron; the evaporating of the remant Co-Ni bearing liquid on a sandy floor above a furnace and below a condensation tower 25m (80ft)high.

Production of copper ore from the mines is thought not to have exceeded 500,000 tons and is best estimated to have amounted to 250,000 tons in the last 63 years of the mines' existence up to 1920, most being won between 1857 and 1877 (Warrington 1981).

B. Resources needed

Pupils will need:

1. Field equipment (clipboard, paper, pencil, rubber, compass clinometer (and spirit level?); weatherproof clothing, hard hats, etc.
2. A copy of the Ordnance Survey 1:2500 map (25 inches to the mile).
3. Copies of the 1:10,560 (six miles to the inch) geological map of the area by Dr F M Broadhurst (in Eagar et al. 1959) and by the British Geological Survey (Trotter 1963). These should be printed and available but not given out until the students have worked on the rocks of the area quite extensively.
4. Copies of other handouts comparable with those used on the excursion in question, but again not distributed until the students have worked extensively on the area and the rocks, and developed an appetite for further learning.

C. The general principles of choosing the route

The general principles involved in choosing a field route at any age level relate to providing satisfactory answers to the following problems (cf. Orion, 1988):

1. Can we reach the starting point early and cheaply?(Alderley Edge is only 20 km from a large urban area: Castle Rocks is only 120m from a lay-by).
2. Can we work safely all day? (Overhanging cliffs are few; shafts can be identified; adits will never be entered; hard hats will be worn)
3. Are toilets available? ((Toilets are provided in the National Trust Car Park and can be visited at the beginning and end of the trip.)
4. Can much be seen and done in a relatively short time? (Localities are c. 100m apart)
5. Can much be done before physical fatigue becomes a problem? (The overall route is only 2 km on the straight, with only one big climb down and up.)
6. Can much be achieved before mental fatigue sets in? (Mental fatigue has been a major problem but can be combated by giving plenty of opportunity for pupils to contribute and by acting on their

suggestions, by reducing the number of concepts tackled, localities used and tasks attempted.)

7. Is there a linking thread between activities at different localities?

For 13-16 year olds:
* learning how to appreciate the relationship between landscape and geological structure (see attainment levels 5, and 7 of Attainment 9 Target of the National Curriculum for Science: DES 1989)
* appreciating that the bases of most wealth are the natural materials (like copper or building stone) which are dug or quarried from the earth (see ATs 6,7,9; DES 1989).

For 16 19 year olds:
* how to plot a geological boundary on a topographic map and so
* understand the basis of geological mapping and the central role of such a document in mineral exploration and economic planning.

8. Are the activities <u>short</u> enough (15-20 mins. at one place), <u>varied</u> enough (using a map; identifying a specimen; using a tool to measure; estimating; plotting on a map or recording in a notebook; putting up conjectures, working with a colleague or alone to test them; discussing with colleagues and/or with the teacher; predicting and searching to test ideas at the right level; listening to an enthusiatic, charismatic teacher, etc.): <u>interesting</u> enough (making links with the rest of the curriculum; with <u>history</u> and <u>industrial archaeology</u>; the castle, the mines (Roeder 1901, Roeder & Graves 1905), with <u>engineering</u> and <u>technology</u>: water supply, transport in and out of the mines; <u>with mineral processing:</u> the ore-treatment plants; with <u>literature</u>: the Arthurian legend (Stanley 1843); children's stories (Garner 1965), with the <u>law</u> (of access underground (Vincent 1986; Dibben 1989); and the scheduling of a Site of Special Scientific Interest), with the <u>geography</u> of planning and conservation.

9. Does the focus of the activities shift? (from sedimentology to mineralisation, from structural geology to the origins of landscape, from mining to conservation)

10. Do the suggested student activities constitute good science teaching? (See Thompson 1982; Fisher and Harley 1988; Groves 1989)

11. Are the teaching strategies varied? (from pupil investigation to teacher-assisted problem-solving, to pupil-assisted teacher demonstration-discussion, to teacher demonstration-disucssion, to teacher talk)

12. Will the teacher be confident enough to take the trip? Is there enough help available? Are there good excursion guides? (The reader will have to judge this for herself/himself! See Thompson <u>in</u> Broadhurst et al. 1970; Warrington and Thompson 1971; Thompson 1985.)

13. Do the activities fulfil the examination requirements of the Boards? (Yes, the trip fulfils most of the requirements and suggestions laid down by NEA, MEG and JMB.)

14. Do the suggested assessment procedures of the boards (see Groves 1988) get in the way of sound teaching and learning? (Alas!! the author often finds that they do, but every attempt is made here to minimise such effects on this route.)

Please note that in preparing this article, more than sufficient suggestions for localities to visit, and more ideas than can be used at any locality on any one day (or half-day), have been provided. The writer leaves the individual teacher to select and adapt the ideas presented and discussed here.

It is also necessary to point out that Alderley Edge is in the care of the National Trust and that hammering and the collection of specimens is forbidden except with the express permission of the warden Richard Littleton, Foresters Lodge, Nether Alderley, Cheshire (telephone 0625-584412), and Mr Moore, the Land Agent, The National Trust Regional Office, Attingham Park, near Shrewsbury, Shropshire. The development of students' curation skills (collecting, referencing, labelling, wrapping, etc.) will have to be learned elsewhere.

The Derbyshire Caving Club, from whom permission should be sought concerning guided tours of the various mines, may be reached through Stephen Mills, Rosebank Cottage, Peover Lane, Chelford, near Macclesfield, SK11 9AW (telephone 0625-861502).

D. The route, the experiences and the general nature of the discussions

Park at the **National Trust** car park **immediately** east of the **Wizard** Restaurant (SJ 860772) <u>or</u> at **Beacon Lodge** (SJ 858776) <u>or</u> set students down at the **lay-by on the B road** immediately south of Castle Rocks and send the bus on to the National Trust car park metioned above. Walk westwards and northwards to Castle Rocks (SJ 856780). All the localities which are mentioned are to be found on Figure 5.

1. <u>Castle Rocks</u> SJ 856780. Pebbly sandstone and conglomerate (Helsby Sandstone Formation HSF: Engine Vein Conglomerate Member EVCM; ageUpper Scythian, Lower Triassic) overlies Wilmslow Sandstone Formation (WSF) of presumed similar age. Descend to the parth beneath the cliff.

<u>Activities and highlights for discussion:</u>
<u>13-16 year olds</u>.

i. Problem recognition and solving:
   a. Discussing/identifying rock types, original horizontal, superposition, structure (dip, strike) in relation to the erosion of the scarp and dip slope.
   b. Discerning a geological boundary which is worth mapping across the area. Students are asked to suggest 10

differences of the rocks above and below a possible boundary (of which two are likely to be suggested as feasible). (Fig.8a)

ii. Measuring dip: amount and direction (compass, clinometer).
iii. Recording data in a notebook and on a map.
iv. Using, reading a geological map.
v. Applications: the siting of the castle, the tourist viewpoint; any signs of mineralisation?

<u>16-19 year olds</u>.
i. Problem recognition and solving.
   a. Principles of stratigraphic classification. <u>Group</u> Sherwood Sandstone Gp); <u>Formation</u> (HSF overlies WSF) <u>Member</u> (EVCM is part of HSF).
   b. Alternative boundaries to map across country.
   c. What kind of unconformity? Angular unconformity or disconformity or paraconformity? Are other explanations (like channel cut and fill) equally feasible and desirable?
   d. Recognition and definition of facies: fluvial (EVCM) (channel-fill or overbank), aeolian (WSF) (dune and/or interdune).
   e. Palaeocurrent data: any differences re facies? What effect will tectonic dip have?
   f. Mineralisation. On the top of the cliff, veins and patches of barite are seen, wherein barite is sometimes > 50% of the rock by volume.
ii. as in ii, iii, iv. for age 13-16.
iii. Applications: how to investigate the mineral potential of the area; how and what to sample; by what means.

2. Walk westwards until **<u>Wizard's Well</u>** is reached (SJ 854780) alongside which is a former mineral trial adit.

Activities and highlights for discussion

<u>13-16 year olds</u>
i. Problem recognition and solving
   a. As in i(a) at Castle Rocks.
   b. The brittle fracture (fault) at Wizard's Well. Argue from the principle of original continuity.
   c. The origin of the "Well". Is it a well? (porosity, permeability, water pressure, gravity force, water table, impermeable mudstone lenses, perched water table, spring v. well v artesian well).
ii. Tracing a geological boundary - plotting one's data on a 1.2500 map.
iii. Constructing an outline succession, especially from the quarried area of the outcrop 50-70m east of Wizard's Well.
iv. Arguing environmental origins (continental? intertidal? marine?) from evidence of fossils, etc. given by the teacher: <u>Euestheria</u> (water flea), reptilean footprint, dessication cracks, scour marks, the cross-bedding in the pebbly sandstones.
v. Applications. Quarrying in the past (what of allowing quarrying

hereabouts today?); water supply, the potential of the "well", and others like it, to supply the district.

<u>16-19 year olds</u>
i. Problem recognition and solving:
   a. Constructing the succession in the lowest part of the EVCM; plotting it as a graphic log (? back at school).
   b. The Wizard's Well fault (strike, dip, throw, nature and direction of slickensides, mineralisation; type of fault; type of stress field).
   c. as above (c).
   d. The rationale for a company or an individual to spend money on a mineral-mine trial adit.
ii. Measuring as in i (b) above.
iii. Recording in a field notebook and on a 25 inch map (1:2500).
iv. Discussing the environment of origin of the EVCM, having decided that the fossils suggest a continental palaeo-environment. (Could it be a river, lake (beach or lake botom?) lake delta, aeolian dune or interdune, floodplain, alluvial fan or scree environment?) If a river environment (because of the channel base cut and fill and the cross bedding, representing the migration of underwater meagaripples and the formation of a bar structure which fills a channel) was it a meandering or braided river?; was it of constant or variable or flashy discharge? (See Thompson 1970b and Collinson in Reading 1986, for help in discussing these problems).

3. Retrace one's steps and walk eastwards past Castle Rocks along the lower path. Ask students to go ahead and test the rumour that two faults have been found in the next 200m (near **Sculpted Face** SJ 857779). Ask the students to 'demonstrate' the existance of the two faults and discuss the matter. Demonstrate how a dotted or dashed line is drawn on a geological map signifying the "uncertain" or "probable" position of the boundary between the HSF and the WSF.

4. Continue eastwards with the same activities until the wall of the **<u>Alderley Reservoir</u>** (1912) is reached, and beyond it, to the east, the **<u>Alderley Beacon</u>** (SJ 859777) at c. 300m (660 ft) above sea level.

Activities and highlights for discussion

<u>13-16 year olds</u>
i. Problem recognition and solving.
a. A reservoir is marked on the map. Is it fed by a giant Alderley Beacon well or spring? What other sources of water could there be (an underground river, artesian well, a borehole?)? In fact, as all over the country, water is pumped up to the top of such a hill, the highest point in the area from very distant sources, in order to create a hydraulic head to keep the water in the pipes of the town below under plenty of 'pressure'.
   b. Why was a beacon erected here? (It was to give warning of the approach of the Spanish Armada.) Suggest how it might function in the technical sense. (Brushwood fires of

variable efficacy were succeeded by cauldrons of burning pitch of constant flame size and luminosity. The Beacon appears on Saxton's map of 1577, an iron cauldron was known in 1799; see Carlon 1979.)

16-19 year olds
i. Problem recognition
   a. What should happen to the geological boundary if the dip is to the SW and the elongation of the scarp changes from NW-SE (Castle Rocks-Sculpted Face) to E-W (near the Reservoir)? (The boundary should shift to the south.)
   b. As i.a. above.
ii. Scratch the soil gently at many places around the Beacon, record your observations on a 1:2500 map, and narrow down the possible position of the HSF(EVCM) and WSF boundary.

5. Visit the **Beacon mineral trial adit** (SJ 860778).

Activities and highlights for discussion

All ages
Problem recognition. Discuss the reasons why a great deal of energy and money might be spent digging this adit exactly here. (A barite mineral vein is seen on the left (east) of the adit along a small fault, the precursor of finding Cu, Pb, Co mineralisation.)

6. Walk eastwards to **the quarry** at SJ 859777 which lies **100m SSE of Holy Well**.

Activities and highlights for discussion

For 13-16 year olds Identify the rock. What was the quarry developed for? (Rough building stone) Would you permit it to be opened up again? Could it be? (No, it is on National Trust Land, held in trust for the nation by a charity.)

For 16-19 year olds
Problem recognition and solving - teacher assisted
a. Identify the rock in this quarry and assign it to WSF or HSF(EVCM).(This proves to be very difficult for students to do so successfully!)
b. Predict the consequences of the rock being WSF or HSF for the mapping of the boundary between the WSF and HSF.
c. Put up hypotheses re this matter and say how you would test them (e.g. by walking to other localities nearby, e.g. Holy Well to the north and scratching the soil all around to make temporary exposures).

7. Walk to the two **Holy Wells** (SJ 859778)

For 13-16 year olds
i. Identify the rock types and formations present, (HSF(EVC) on WSF), and the dip of the rocks.
ii. Read off the height of this locality from your map (c. 500ft).

iii. Test the idea that these wells are comparable to that at Wizard's Well. (They are perfect examples of springs developed on a perched water table.)
iv. Identify the nature of, and measure the direction of, a mineral vein. (A baritic vein trends SE-NW in the main face.)
v. With the help of your teacher and reading your geological map, understand the need for the Holy Well Fault, aligned NNW, in the valley to the west, probably to be drawn parallel with the barytic mineral vein which can be seen. Relate the erosion of the valley to the presence of the fault.
vi. Name a mass movement feature which is present here (landslipped blocks) and explain orally how it might have originated.
vii. Applications. For what purposes was a small quarry developed on the top of Holy Well? (For building stone of ornamental quality)

For 16-19 year olds
1. Problem recognition and solving - teacher assisted
   a. Identify the rock types and the formations present.
   b. Measure (or estimate) the dip of the rock formations.
   c. Consider the geological boundary you have traced from localities 1-5 and its height A.O.D. and the evidence of localities 6 and 7 (the present one). Suggest hypotheses to explain the geological structure of the area between Holy Well and Alderley Beacon which will reconcile these observations (fold(s), fault(s), fold + fault, etc. might be suggested). Discuss these ideas with your teacher and decide upon the best and simplest solution (the latter illustrating Ockham's principle).
   d. Plot the boundaries of the WSF-HSF and the proposed fault on your map with the help of your teacher.
   e. Predict the course of the boundary of the WSF-HSF across the hillside to the east. (It should be suggested that it will "rise" across the contours, since the dip is still inclined to the SW.)
   f. Predict the rocks which should appear at the next locality Twin Shafts (SJ 859779) (the location of which can be seen across the valley 150m to the northeast), given that there are no folds or faults in the intervening ground.

8. Walk northeastwards down the slope and up the valley side to **Twin Shafts** (SJ 8597799), having been informed that we are next to explore the first part of an extensive mine complex known collectively as the **Stormy Point Mines** (see the map: Fig.6). Students should be encouraged to look out for the first signs of mining and economic minerals. (In fact the path takes them up the mine spoil heap.)

Activities and highlights for discussion

For 13-16 year olds
a. Collect individually, and assemble at your teacher's feet, all the economic minerals which you think you have found: malachite (green), azurite (sky-blue), wad (black), chalcopyrite (black), pyromorphite (citrus green/yellow), limonite (rusty-brown), hematite (red), galena (grey), barite (white) and possibly calcite (white). The teacher can unveil his/her reference collection hereabouts if the students' collections are poor or inadequate.

Suggest which economic elements might have been worked here for profit (copper, lead, cobalt, nickel). Which are gangue (worthless) minerals? (Barite and calcite) Discuss the <u>tenor</u> of the ores. (Only Cu is present in abundance.) Suggest where the minerals may have come from. (There will probably be few suggestions for the origin of the elements in the ores, but the question is worth asking - for the educatioinal reasons for this approach see the CLISP rationale (Driver et al. 1985).)

b. Working in pairs, locate and point out where mine shafts and adits may be present - but do not walk into them.

c. Identify the rock types and formations that are present. (HSF(EVCM) pebbly sandstone is easy to see; WSF fine red - pink sandstones will be less easily seen except on the southern side of the outcrop.)

d. Locate and identify the structure along which mining has proceeded. (A double fault zone should be spotted - **the Stormy Point Fault.**)

e. Draw a rough, scaled diagram of this locality, as seen from the south, marking shafts, adits, faults,slickensides, bedding planes, direction of dip, pebbly sandstone, conglomerate, mudstone bed, very micaceous horizon, etc. <u>or</u> Draw a roughly scaled large-scale plan of this locality, marking on it most of the features listed above.

<u>For 16-19 year olds</u>

1. <u>Testing your predictions and recognising problems</u>
   a. Identify the rock types present at the locality.
   b. Observe the features due to mining - shafts and adits - and their relationship to any geological features present.
   c. Measure and record on your map and in your notebook, dip, strike, etc.

2. <u>Problem solving</u>
   Explore the outcrop and be prepared to demonstrate to your colleagues and your teacher the geological context of the locality, pointing out the present of WSF, HSF(EVC), faults, shafts (which intersect the now worked-out mineral veins), adits (which were constructed in order to enter the mines and work the ores along the strike of the veins).

3. Discuss with your teacher where the geological boundary which you have been following should be drawn on the north and south of this Stormy Point Fault.

9. For sixth formers only: Walk westwards steeply downhill, following the line of the Storm Point Fault (aligned 290°) which you have just discovered. First, after 50m, you will come to a small outcrop of pebbly sandstone (EVCM). Discuss whether this should be assigned to the north or south of the Stormy Point fault. Notice, but avoid, the depression (an old shaft head) in the bottom of the hollow. Continue to scramble down slope until an outcrop is reached some 100-150 metres from Twin Shafts. This is a wet and messy outcrop - **Lower Twin Shafts** - at SJ 858780.

Problem recognition and solving: teacher-assisted

i. Identify the rock types (WSF).
ii. Identify the geological structures: (dip is not well seen but is still to the southwest; a fault complex is aligned 290°, dipping to the north).
iii. Suggest the relationship of this feature to those at Twin Shafts. (This is the same fault line, but is of 30m lower altitude.)
iv. Comment on the degree of mineralisation present. (The rocks are reddish in places and only barite gangue can be suspected.)
v. What is the purpose of the adit? (This is the lowest working level and the drainage sough for the Stormy Point Mines. See the map of these mines Fig.6.)

10. Retrace one's steps by scrambling uphill to Twin Shafts and then by climbing still further uphill towards **Stormy Point**, SJ 860779.

On the way students will see the expression of the baritised faults which they had first identified at Twin Shafts and they will observe the metal-capped head of a deep shaft which has been cleaned out recently (1988) by the Derbyshire Caving Club which have leased the mines and are restoring their working levels and shafts (Dibben 1989).

On Stormy Point, the geology is particularly well exposed, partly through human erosion, which the National Trust finds hard to control. The junction of the WSF and HSF (EVCM) is well displayed, but is broken by the Stormy Point Fault, throwing down c.10m to the north.

Discussion highlights and activities

For 13-16 year olds

1. Planning an investigation. Working in pairs or threes take 5 minutes to plan an investigation of the area known as Stormy Point which extends from the Pilkington Memorial and the triple junction of the Parish Boundaries on the north, to Devil's Grave on the south, from the shaft on the west and to the steep slope to the northeast, down which students will not be allowed to go. (Note that the area has been defined so that no student will be more than 40m away from the teacher in the centre of Stormy Point and certainly not out of sight.)

2. Carry out your investigations for 45 mins on your own by exploring all the geological features of the area. Your teacher will watch you and will assess your ability to work methodically in a disciplined and orderly way, making appropriate scaled diagrams, sections and plans in your field notebooks. Pay great attention to significant areas and details. You may ask your teacher for informal help at any time in the first 15 mins. and these interchanges will not affect the mark which is awarded to you.

3. <u>Report orally</u> on your findings and <u>demonstrate your ideas</u> to your colleagues afterwards. (This will involve: describing the WSF and the HSF(EVCM); tracing their junction with the help of the

thick red mudstone band which has so often been seen on the Edge to be associated with this boundary; tracing the Stormy Point Fault planes from west to east and detecting that 2 faults splay into as many as 4; finding adits on the south east and investigating exploration holes like Devil's Grave; tracing baritic mineral veins of (i) ragged-anastomising and (ii) straight-edged varieties; locating the presence of north-south faults in the eastern part of the area, etc.)

4. An alternative exercise to 1, 2, 3 above, might be the following which leads to a simulation, role-playing exercise back at school.
What landscape features do you see on the northeast downslope side of Stormy Point? (This is a large area of landslipped blocks of EVCM.) Investigate this area for 30 minutes, making notes on your findings. Be prepared, after a homework for preparation, to speak in class to the chairman and members of the Environmental and Planning Committee of the County Council on the nature and origins of these features and their likely future stability. Should this area be closed to visitors at any time in the year? Should the Natioinal Trust rope off any parts or designate pathways through the area?
From the viewpoint towards the northeast afforded by Stormy Point, it is possible to point out the site of the Northwest Water Authority's Lower House Farm Borehole, drilled c. 1970 at SJ 867785 and the Clockhouse Farm observation borehole at SJ 866784, some 200 metres away to the SSW. Both are sited in the WSF, a favourite aquifer in these parts. The purpose(s) of the latter borehole, and many like it, can be discussed by the students in terms of monitoring the level of the water-table, sampling the water chemically in terms of insoluble constituents and biologically in terms of organic purity, measuring the extent of the "cone of exhaustion" which develops around a borehole when the main hole is pumped hard (several million litres (gallons) per day) on a 24-hour or week-long test.
Experimental work back at school or college on the porosity and permeability of sandstone rocks is clearly desirable and loose specimens of rock might, with the permission of the warden, be collected by the students specifically for this purpose.

For 16-19 year olds
One exercise which has been carried out by many groups is the mapping of the area known as Glaze Hill and Saddlebole. If the teacher locates himself/herself at the Memorial and all the students carry emergency whistles, there should be no trouble re safety. All students will work within 200m of the teacher. 90 mins may be allowed for this exercise.

11. Return from Stormy Point to the **National Trust car park** by walking eastwards to the area of Doc and Pillar Mines (SJ 861779) and demonstrating, or working out, the geology of this area - the eastern extremity of the exposure of the Stormy Point Fault. Wild-west films have been shot hereabouts - a novel use of a red sandstone outcrop! If time permits, have students assemble a collectio.n of mineral specimens in the manner described at Twin Shafts. If time permits, descend to the entrance to the Hough Tunnel immediately below Pillar

Mine. Here the DCC have dug out the old level for several hundred metres into the hill.

Return southwards via Opencast (SJ 861777), Old Alderley Quarry (SJ 867777), Engine Vein Mine (SJ 860775)), Beacon Lodge (SJ 858776)), Church Quarry (SJ 8597790), Wood Mine (Sandstone Member of HSF) to the Wizard Restaurant. View the shaft head of the Wizard's Well Cobalt Mine (SJ 859 773). Walk east into the National Trust car park (SJ 860772).

E. Fulfilment of course and examination requirements

Attainment Target 1 of the National Curriculum for Science, "Exploration of Science" (DES 1989), is framed in terms of the following broad categories of investigation; pupils are expected to:

1. Plan, hypothesise, predict.
2. Design and carry out investigations.
3. Interpret results and findings.
4. Draw inferences.
5. Communicate exploratory tasks and experiments,

In the foregoing activities and discussions suggested for an excursion to Alderley Edge, all of these categories are covered. Even a limited selection of the tasks outlined would serve to cover most lines of investigation.

With respect to the MEG Geology GCSE Assessment Schedule (1989), all 50 categories could be assessed for each individual should most of the activities and exercises cited in Section D be attempted. It is the author's experience, however, and that of his colleague Alastair Fleming, that such an assessment scheme is unwieldly and often gets in the way of good learning and teaching.

All the broad categories covered by the NEA GCSE Geology Syllabus (1989) - A. Attitudes to conservatioin and safety; B. Ability to work methodically and organise work; C. Ability to observe accurately and to propose further investigations; D. Ability to use equipment and measure in a quantitative way; E. Ability to record information in a field or laboratory notebook - are covered by the activities proposed for the excursion. With respect to the more detailed suggestions by the Board for possible investigations, specified in paragraph 9 of the syllabus, only six out of twenty-five exemplars are not attempted during this single Alderley excursion, and this is because the specimens and rock types involved (body fossils, cleaved and other metamorphic rocks, igneous rocks, limestone rocks) are not available at Alderley Edge. In any case, the Board merely offers a useful list of exemplars of activities which might be carried out.

The excursion affords opportunities to develop most of the skills abililties and attitudes specified in the JMB Geology Advanced Level Syllabus (1989).

References

Bakewell, R. 1811 Account of a Cobalt Mine in Cheshire. The Monthly Magazine 31, p.7-9.

Bakewell, R. 1813. An introduction to Geology London. (See appendix VI for "Cobalt Mine at Alderley Edge in Cheshire").

Broadhurst, F.M., Eagar, R.M.C., Jackson, J.W., Simpson, I.M., Thompson, D.B. 1970. No.7 The Area around Manchester. Geologists' Association Guides. Colchester, Benham & Co. 51pp.

Carlon, C.J. 1979. The Alderley Edge Mines. Altrincham, J.Sherrat & Sons. 144pp.

Carlon, C.J. and Thompson, D.B. 1981. Aspects of mineralisation within the Cheshire Basin (Abstract) Journal Geol. Soc. London, 138, pp.220 only (see Conference Report by Ineson, P.R. 1981 Low-temperature mineralisation. Jl. Geol. Soc. London. 138, pp 217-220)

Chadwick, R.A. 1985. Permian, Mesozoic and Cenozoic structural evolution of England and Wales in relation to principles of extension and inversion tectonics. in Whittaker, A. (Ed.)pp.9-25.

Collinson, J.D. 1986. Alluvial sediments. in Reading, H.G. (Ed.) pp.20-62.

DES 1985. GCSE: The National Criteria Science. London, HMSO.

DES 1989. The National Curriculum Science. London, HMSO.

Dewey, H and Eastwood, T. 1925 Copper ores of the Midlands, Lake District and the Isle of Man. Spec. Rept. Mineral Resources of Great Britain 30, 5-18.

Dibben, N. 1989. Alderley Edge - the legal background. Derbyshire Caving Club News 2, pp.6-8.

Driver, R., Guesne, E. and Tiberghien, A. 1985. Children's Ideas in Science. Open University Press, Milton Keynes.

Eagar, R.M.C., Broadhurst, F.M. and Jackson, J.W. 1959. The Area around Manchester. Geologists' Association Guide No.7. Colchester, Benham & Co. 32pp.

Fisher, J.A. and Harley, M.J. 1988. Earth Science fieldwork in the secondary school curriculum. Peterborough, Nature Conservancy Council, 36pp.

Garner, A. 1965. The Weird stone of Brisangamen. London, Collins.

Groves, W. 1988. Fieldwork and its assessment in GCSE geology. Geology Teaching 13 (4), pp.171-174.

Groves, W. 1989. A survey of GCSE geology teachers and their attitudes to fieldwork. Teaching Earth Sciences 14(2), pp.46-50.

Johnson, N.C. 1984. Wizard's Well Mine, Alderley Edge - Early Mineteenth Centruy Cobalt Workings. The Journal of the Derbyshire Caving Club, pp.17-21.

Naylor, H., Turner, P., Vaughan, D.J., Boyce, A.J. and Fallick, A.E. 1989. Genetic studies of red bed mineralisation in the Triassic of the Cheshire Basin. Journal of the Geological Society, London 146, pp.685-699.

Orion, N. 1989. Field Trips in the Israeli high school geology curriculum. Teach ing Earth Sciences 14(1), pp.25-28.

Reading, H.G. (Ed.) 1986. Sedimentary Environments and Facies. Oxford, Blackwell Scientific 615pp.

Roeder, C. 1901. Prehistoric and subsequent mining at Alderley Edge. Transactions of the Lancashire and Cheshire Antiquarian Society 19, pp.77-118.

Roeder, C. and Graves, F.S. 1905. Recent archaeological discoveries at Alderley Edge. Transactions of the Lancashire and Cheshire Antiquarian Society 23, pp.17-29.

Sibson, R.H., Moore, J. McM., and Rankin, A.H. 1975. Seismic pumping- a hydrothermal fluid transport mechanism. Quart. Jl. Geol. Soc. London 131, pp.635-659.

Stanley, L.M. 1843. Alderley Edge and its Neighbourhood. Macclesfield, J. Swinnerton; reprinted 1972, Didsbury, E.J.Morten.

Stanton, R.L. 1972. Ore petrology. New York, McGraw-Hill.

Thompson, D.B. 1970a. The Stratigraphy of the so-called Keuper Sandstone (Scythian -? An sian) in the Permo-Triassic Cheshire Basin. Quart. Journal of the Geological Society of London 26, pp.151-181.

Thompson, D.B. 1970b. Sedimentation of the Triassic (Scythian) red pebbly sandstone in the Cheshire Basin and its margins. Geological Journal 7, pp.183-216.

Thompson, D.B. 1970c. Itineraries VIII to XI: Triassic Rocks. pp.32-51 in Broadhurst, F.M. et al.

Thompson, D.B. 1982. On discerning the purposes of geological fieldwork. Geology Teachi ng 7(2), pp.59-65.

Thompson, D.B. 1985. Field excursion to the Permo-Triassic of Cheshire and East Irish Sea Basins (4th edition) Ches ter, Poroperm-Geochem Ltd. 172pp.

Trotter, F.M. 1963. 1:10560 Geological Map on the six-inch scale of Alderley Edge: Sheets SJ 87 NW and SJ 87 NE. Leeds, Institute of Geological Sciences now Keyworth, British Geological Survey.

Vincent, P. 1986. Law and Mineral Land Management. Betley (Staffs), Smith Vincent & Co. 113pp.

Warrington, G. 1965. The Metalliferous Mining District of Alderley Edge, Cheshire. Mercian Geologist 1, pp.111-113.

Warrington, G.W. 1980a. The Copper Mines of Alderley Edge and Mottram St Andrew, Cheshire. Journal of the Chester Archaeological Society, 64, pp.47-73.

Warrington, G.W. 1980b. The Alderley Edge Mining District. The Amateur Geologist, 8(1), pp.4-13.

Warrington, G. et al. 1980. A correlation of Triassic Rocks in the British Isles. Speccial Report No.13 of the Geological Society of London. London, Geological Society.

Warrington, G. and Thompson, D.B. 1971. The Triassic Rocks of Alderley Edge. Mercian Geologist 4, pp.69-72.

Whittaker, A. (Ed.) 1985. Atlas of onshore sedimentary basins in England and Wales. Glasgow, Blackie, 71pp.

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