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RECENT BENTHIC FORAMINIFERIDA AS INDICATORS OF POLLUTION IN RESTRONGUET CREEK, CORNWALL

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INTRODUCTION

Following a discharge of acidic mine water highly contaminated with heavy metals from Wheal Jane tin mine (13.1.92), a preliminary investigation has been made to determine the response of foraminifera when exposed to polluted water. The initial results of the research are given in this paper.

PREVIOUS RESEARCH

There is no known database of foraminiferal species distribution in Restronguet Creek, nor has any previous investigation of the usefulness of benthic foraminiferans as pollution indicators been carried out at this location. The potential use of benthic foraminiferans as indicators of pollution in other estuaries has, however, been examined by a number of workers.

Recent work carried out by Sharifi *et al.* (1991) on Southampton Water found abnormal foraminiferal test growth resulted from exposure to increased levels of Cu and Zn. Alve (1991) and Ellison *et al.* (1986) concluded that a low abundance of living foraminifera and an increase in diversity away from the source of contamination is indicative of metal contamination.

HISTORICAL PERSPECTIVES

Restronguet Creek provides a unique site for investigation because of the additional complication of the long history of heavy metal contamination.

Within the catchment areas of the rivers Kennal and Carnon which feed into Restronguet Creek (Figure 1), metalliferous mining has taken place for several centuries (Barton, 1967) and prior to the recent discharge from Wheal Jane, both rivers, and in particular the Carnon, have received discharged mine waters. Prior to 1854, when the precipitation technique was initiated to remove copper and other metals, untreated water was discharged (Hamilton Jenkin, 1963).

Of the mines which drained into the Carnon and Kennal, Wheal Jane was for, several years, the last working mine. The area had, therefore, experienced a period of quiescence with respect to mine water discharge, with no major discharges noted (Simpson, 1992, personal communication). The abandoned mines are, however, flooded and remain sources of contaminated leachate. There also remains the unanswered question of the amount of contamination caused by the natural processes of chemical and physical weathering of metalliferous veins.

The most recent discharge occurred after the mine ceased working in February 1991, as up until this time the mine had been kept dry. After closure Wheal Jane was allowed to flood. Following prolonged heavy rain and strong winds the existing treatment measures failed and 320 million litres of untreated water discharged into the Carnon over a period of 60 hours (Carnon Consolidated, 1992). The concentrations of heavy metals in the sediment detected after this discharge are graphically illustrated by Figure 2.

WATER CONDITIONS

Freshwater flow is often vigorous with respect to the Kennal and Carnon and tidal influence is restricted to below Devoran road bridge [SW 790 394]. At low water extensive areas of mudflats are exposed, with small isolated areas of saltmarsh. Salinities vary from 5ppt at Carclew in the winter to a maximum of 31ppt in the summer. Further down the creek at Harcourt, values rise to 30ppt in the winter and 33ppt in the summer. Carrick Roads, the estuary of the Fal (Figure 1), has salinities of a normal marine environment; 34ppt.

METHODS

With increased depth the abundance of living foraminiferans decreases (Murray, 1991). The cores Boltovoskoy (1966) took from Deseado Creek, Chile showed diversity and the number of specimens per cc. of sediment decreased with increased depth. Boltovoskoy (1966) did, however, find living foraminiferans at a 16 cm depth but suggested that the substrate type and the depth of the oxidised zone would be controlling parameters. Similar work carried out by other researchers also found living foraminiferans existed at these greater depths (Buzas, 1969, 1974; Steinack and Bergstein, 1979).

This preliminary investigation is limited to foraminiferal response to a recent contaminated discharge and the ratio of living to dead individuals is an important consideration. Sampling, therefore, was restricted to a 1 cm depth as sampling deeper would distort the live/dead ratio and would be unrepresentative.

The sample sites selected follow lateral transects along both sides of the creek within the intertidal sections (see Figure 1). Following standard sampling techniques a 10 cm diameter ring was inserted into the sediment to a depth of 1 cm and the enclosed sediment removed by a modified dish to plastic jars containing buffered formalin. Vigorous shaking distributed the preservative.

The samples were processed in the laboratory by wet sieving on a 63 micron sieve. The >63 micron residue was transferred to a bowl and immersed in Rose Bengal (Walton, 1952) for 45 minutes to stain the protoplasm within the tests of the foraminiferans alive at the time of sampling or only recently dead. Further wet sieving removed excess stain and the residue was dried overnight at 60°C. Each dried sample was sieved through a sieve stack and the retained fractions weighed. The 250 micron and 125 micron fractions were randomly picked and a minimum 301 specimens mounted onto a grid slide. The data have been reduced to percentages for relative abundance of living and abnormal test growth. The distinction between normal and abnormal is made by reference to the type species (see Plate 1). Those specimens considered abnormal show additional chamber growth whereby one chamber is superimposed upon another, enlarged final or penultimate chambers, protruding chambers, multiple distorted chambers, twinned tests and uneven chamber or suture shape.

RESULTS

The highest percentage occurrence of living specimens was found at Tallack's Creek and this is co-incidental with a high percentage occurrence of abnormal test growth.

Sample TC3 (Figure 1) gave the highest values of stained tests (37%). The number of tests showing abnormal growth (see above) is similarly high (14%), of which over half were living (8%). As Figure 3 shows, a trend is evident and a horizontal gradient is defined, whereby the number of deformed and undeformed living both decrease away from the discharge point.

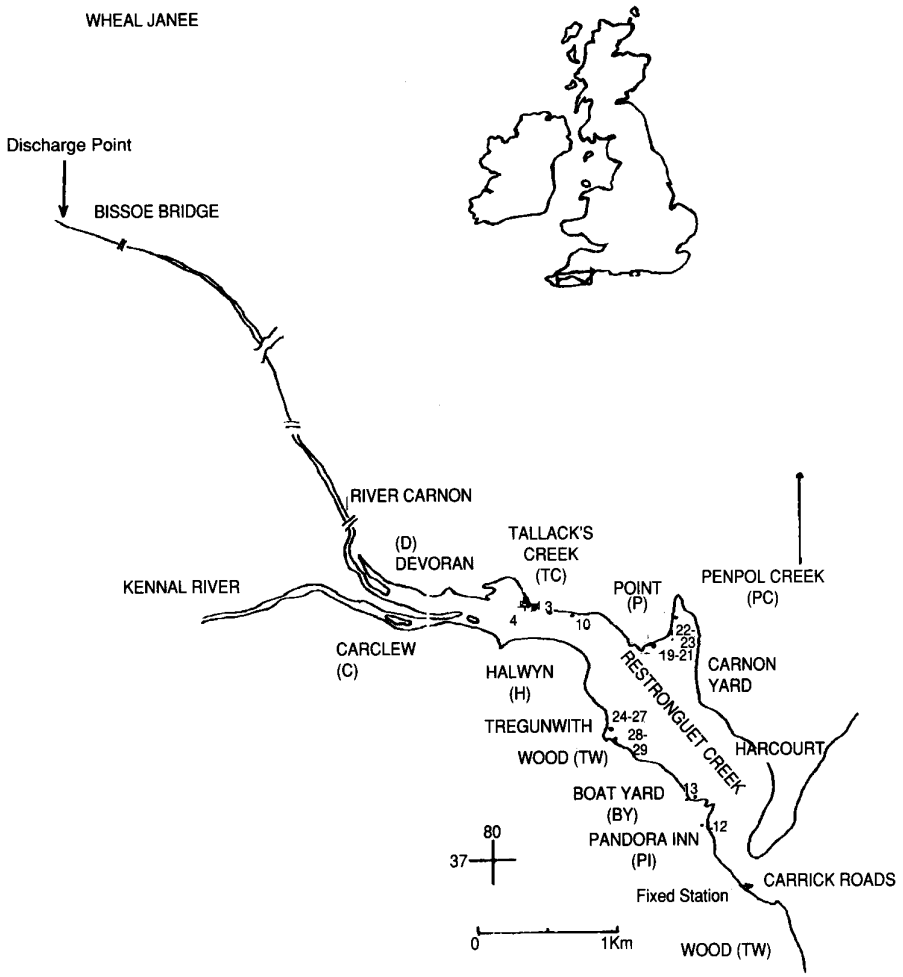


Figure 1: Locality map showing sample stations, discharge point and spatial relationship to Wheal Jane tin mine. Abbreviations of the stations are shown, eg. TW represents Tregunwith Wood.

Tregunwith Wood has the lowest percentage abundance of living (3%-8%) and deformed living specimens (<2%). Sample TW24 is the exception with 19% living and 2% living deformed (Figure 4). A direct correlative trend is again evident between live deformed and undeformed, but the abundance of living increases at Pandora Inn, furthest away from the point discharge.

The correlation between living deformed and undeformed foraminiferans is positive, but some of the points scatter about the line as shown by Figures 5a. and 5b. The correlation is not, therefore, strong.

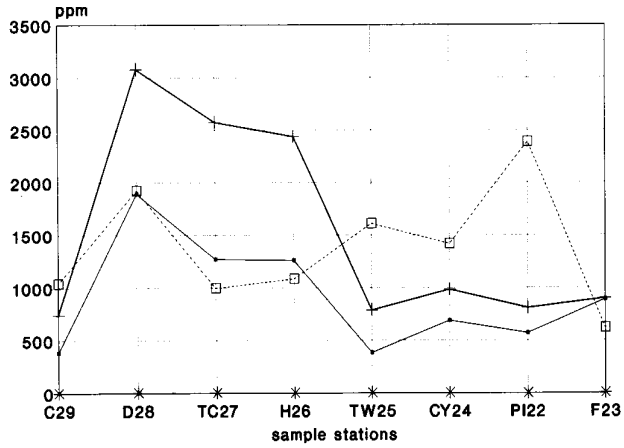


Figure 2: Heavy metal contamination of sediments, Restronguet Creek. Data supplied by the NRA (13.5.92).

SPECIES DOMINANCE

The species *H. germanica* dominates both the live and dead assemblages, accounting for a maximum total of 89% of sample P20 of which 13% were living. The maximum abundance of living *Haynesina germanica* was found at location TC3, accounting for 95% of the living total of 37%. The two species *E. williamsoni* and *A. beccarii* show low abundance and do not exceed 30% and 6% respectively of the total species distribution. The abundance of living is similarly low (see Figures 6a and 6b).

POPULATION DENSITY

Population density (living and dead) is highest on the south side of the creek. Tregunwith Wood and the Boat Yard have values c.3000 individuals per 10 cm^2. The tests at Tregunwith Wood are in pristine condition. Few specimens show abrasion or other features indicative of transportation and/or low pH conditions. The condition of the tests from the Boat Yard show some of these features. The total population density decreases downstream to less than 800 individuals per 10 cm^2 at Pandora Inn.

On the north side of the creek at Tallack's Creek there is a paucity of specimens, with 127 per 10 cm^2 (sample TC1). Density increases away from the discharge point with an average value of 560 individuals per 10 cm^2 at sample location Point.

DIVERSITY

There are 3 indigenous species forming the living assemblage and the Alpha Index is less than 1 (Fisher *et al.,* 1943). The three species belong to the Suborder Rotaliina. In addition to the indigenous species

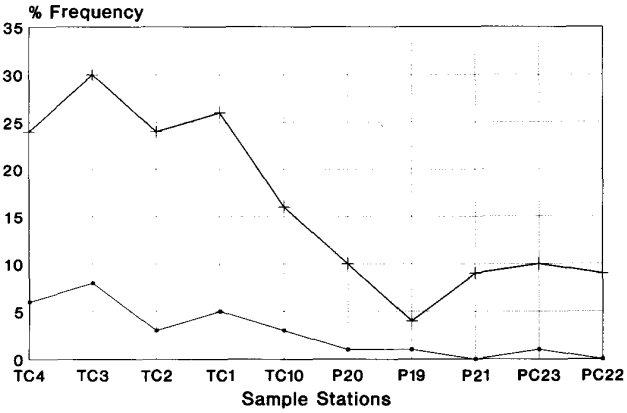


Figure 3: North side of creek showing the dual relationship between living deformed and undeformed.

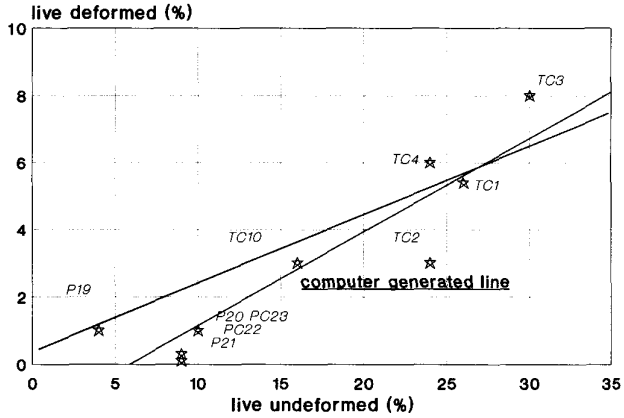


Figure 5a: North side- trend diagram of living undeformed vs deformed.

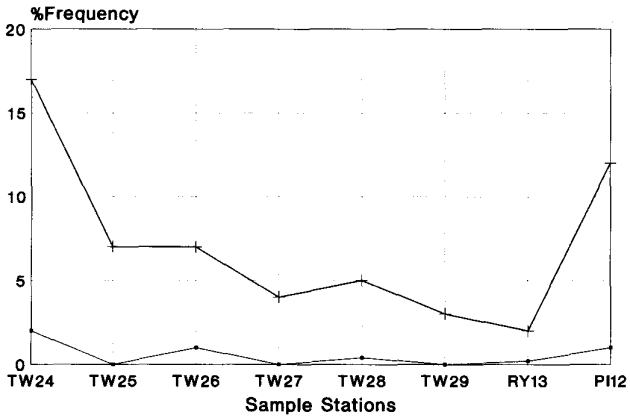


Figure 4: South side of Restronguet Creek.

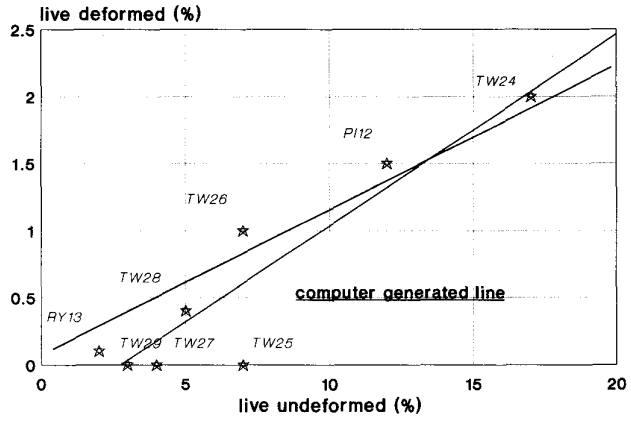


Figure 5b: South side.

there are a few randomly distributed species, for example, *Quinqueloculina dimidiata* Terquem and *Jadammina macrescens* (Brady). These were restricted to the dead assemblage and diversity increases slightly as a consequence to a maximum of 5 species. The random and impoverished distribution of these minor species leads to the conclusion that they are an allocthonous influence from adjacent environments and/or reworked from depth.

DISCUSSION

The data derived from this preliminary investigation shows a bimodal trend which may be assigned to a pollution control.

Tallack's Creek shows a positive correlation between living deformed/undeformed and the highest percentage abundance of living is here, nearest to the discharge point. This is contrary to the findings of Alve (1991) and Ellison *et al.* (1986), which concluded that a low abundance of living foraminiferans proximal to the source is indicative of a pollution control. An increase in live foraminiferan abundance proximal to the source may suggest that the community there is more specialised and able to cope with high levels of heavy metals. The decrease in the relative abundance of living deformed foraminiferans on both sides of the creek away from the discharge point does fit the Sharifi *et al.* (1991) model, whereby fewer deformed specimens were encountered when there was no spatial relationship with a source.

The majority of samples taken from Tregunwith Wood have low living abundance and deformed specimens, but high total population density. There is a small increase in the number of living foraminiferans at Pandora Inn and this may indicate an inability to cope with heavy metal pollution. The dilute and dispersal effects of the relatively unpolluted river Kennal may be affecting the results at Tregunwith Wood, but this needs to be investigated further.

Low diversity is generally accepted as normal within an estuarine environment because of the variable conditions (Murray, 1991). The absence of the euryhaline agglutinated species, however, poses an anomaly. Living agglutinated taxa are present in the Erme estuary samples taken in 1991. At most locations the species *Miliammina fusca* (Brady) was found to be the dominant species. Research by Hart and Thompson, 1974; Murray, 1973, 1991; Boltovoskoy, 1976 and Steinack *et al.* 1979, for example, has found agglutinated species to be typical of an estuarine assemblage. The reasons for the apparent absence of the euryhaline agglutinated species is uncertain. If the variables salinity and temperature were controlling factors (Lidz, 1965), then the three indigenous calcareous euryhaline species would also be affected as they share similar tolerance thresholds (Greiner, 1969). Absence due to complete dissolution within the sometimes acidic water conditions is also unlikely as this implies selective dissolution and low pH would be more effective upon calcereous tests than agglutinated forms (Jonasson and Patterson, 1992; Murray, 1973).

The data suggest that the three species present can tolerate high concentrations of heavy metals, but other euryhaline species have lower tolerance thresholds.

FUTURE WORK

Sampling of Restronguet Creek and the control estuary, the Erme will continue at seasonal intervals. Absolute and relative abundance of deformed and undeformed living will be determined and correlated with the concentrations of heavy metals within the sediment. The tests will be analyzed by microprobe (Jeol 6100) to detect the levels of heavy metal accumulation and this data correlated with spatial relationships to the discharge point.

Other influences and likely causes of pollution which may control

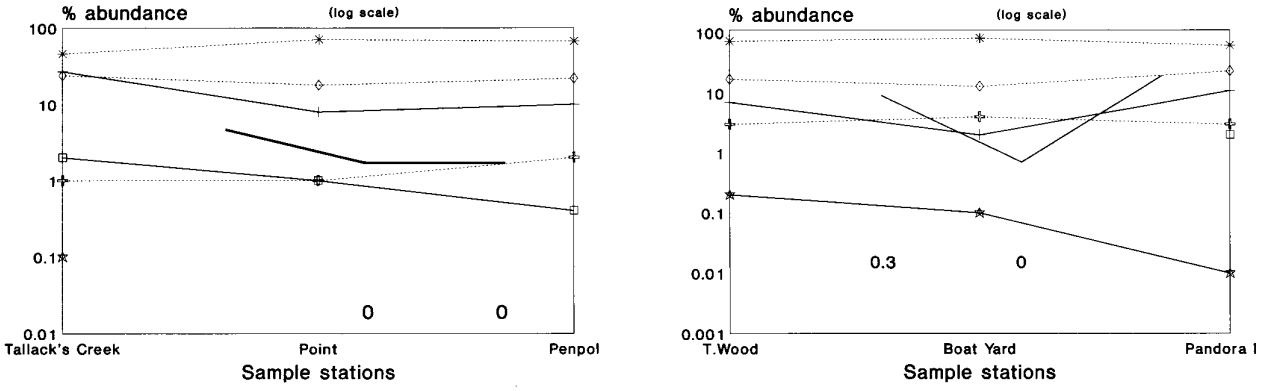
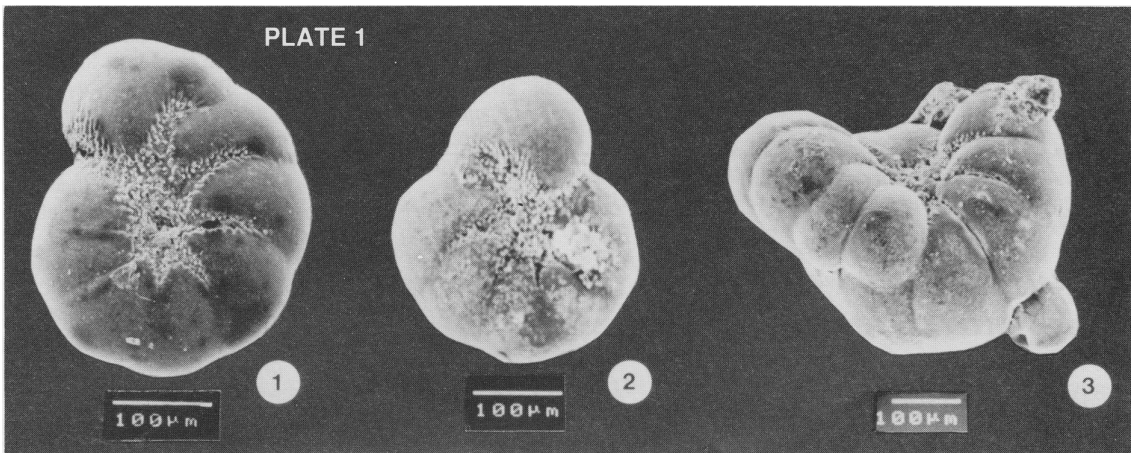
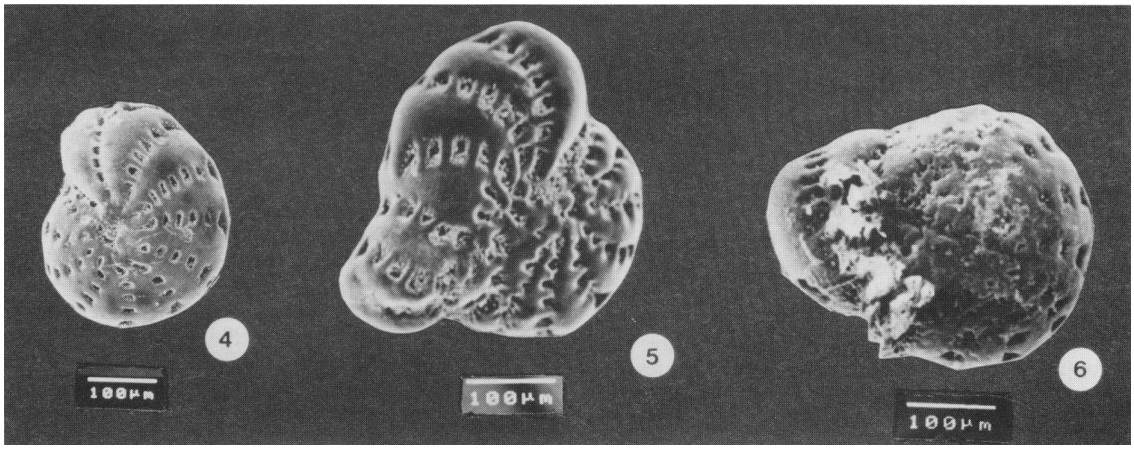


Figure 6: *% distribution of each species and associated abundance of living specimens found on the north side (a) and south side (b) of the creek.*



1. Haynesina germanica type species (300µm). 2. H. germanica, abnormal chamber growth. Last chamber is enlarged and protruding (250µm). 3. H. germanica, multiple chamber growth (350µm).



4. Elphidium williamsoni type species (300µm). 5. E.williamsoni, protruding chambers (300µm). 6. E.williamsoni, twin (325µm).

foraminiferal distribution (absence of agglutinated taxa) and test form will also be investigated.

Cores will be taken and dated to determine past foraminiferal response to heavy metal pollutions with respect to abnormal test growth and test accumulation of metals. The concentrations of heavy metals within the sediment will also be determined.

The future proposals for the treatment of mine tailings and water should ensure that contaminated water is not discharged into the Carnon again. Future sampling for benthic Foraminiferida will provide a useful monitoring technique of the proposed treatment at Wheal Jane and the present research will provide comparative data.

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Notice

REGIONALLY IMPORTANT GEOLOGICAL AND GEOMORPHOLOGICAL SITES IN DEVON: PROGRESS WITH EARTH SCIENCE CONSERVATION

P. GRAINGER, M. ANDERSON, P. CHAMBERLAIN, M.B. HART, B. MELOY AND K. MOORE

INTRODUCTION TO RIGS

In 1990, the Nature Conservancy Council launched its Earth Science Conservation Strategy which included the concept of RIGS (Regionally important geological and geomorphological sites). The aim is to notify sites whose geological significance is not sufficient to attract statutory protection as Sites of Special Scientific Interest (SSSI), but which are considered worthy of conservation on account of their local value for earth science eduction, for research, for historical or aesthetic reasons.

The setting up and running of local RIGS schemes (usually county by county) has been encouraged by NCC, and now English Nature, by forming groups of interested volunteers. The initial tasks of a RIGS group are to gather local site information, to select appropriate sites from those nominated, to involve landowners and to notify local authorities. In the longer term the RIGS group should monitor, manage and enhance sites, and add or remove sites from the list.

DEVON RIGS

The Devon Wildlife Trust organised an inaugural meeting for a Devon RIGS Group in April 1991, at Exeter Museum, to which all potentially interested parties were invited. These included local authorities, museums, local geological societies, higher education establishments, conservation bodies and other professional geologists. This meeting agreed the establishment of a Devon RIGS Group and a smaller Steering Group was self-selected, which has met at regular intervals since (this is comprised of the authors listed above). The Steering Group reports back to the main group at occasional meetings.

Having studied the guidelines for RIGS schemes, the Steering Group devised a site nomination card and accompanying explanatory notes for circulation to all interested parties. It has also investigated the possibilities of funding (so far without success), obtained publicity through the media, and clarified the list of SSSIs in Devon.

One important policy decision was made, which was to exclude coastal sites from the scheme at the present time, but to review this policy later. On receipt of completed nomination forms or of information in any other form, for example lists of sites by name and grid reference only, a database has been established on PC at Exeter Museum. About one hundred sites were nominated during 1992, irregularly distributed around the county.

In order to make a start on the notification procedure, the county was divided into its ten local authority districts and the smallest one, Exeter City, chosen for this purpose. Five sites were selected as follows:

Pinhoe Brickpit (Crackington Formation)

Pocombe quarry (Exeter Permian Volcanics)

Heavitree Quarry (Permian Breccia)

Bishop's Court quarry (Permian Sandstone)

Ferry Road, Topsham (Quaternary Fluvial Deposits)

These sites are currently in the process of being discussed with landowners and notified to the local authority.

FUTURE DEVELOPMENT

There must still be many potential RIGS sites which have not been brought to the attention of the Steering Group and the process of seeking nominations will continue as long as is necessary. The assistance of Ussher Society members in this important task is requested.

Selection and notification will proceed in other local authority districts, as sufficient coverage is achieved. Progress has been less rapid than anticipated, partly because the Steering Group is composed entirely of full-time professionals. Information on notified sites will be made available as the scheme develops.