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A review of the known biological characteristics of the Great Meteor East site together with a sampling programme for a biological site assessment

H.S.J. ROE

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ABSTRACT

Existing biological information on GME is reviewed. In common with most other oceanic areas there is very little data available from depths below 2000m. There is virtually no direct benthic information and none at all on the midwater/benthic boundary layer. Existing data from a wider geographic area are relevant to GME but the applicability of such data varies according to the hydrography. A sampling programme is outlined which will allow a comprehensive quantitative and qualitative assessment of the midwater and benthic ecosystems. Particular attention will be paid to the interactions between benthic and midwater communities just above the sea floor.

Keywords
299 177 (Research requirements), 225 (ocean sites).

This work has been commissioned by the Department of the Environment as part of its radioactive waste management research programme. The results will be used in the formulation of Government policy, but at this stage they do not necessarily represent Government policy.

CONTENTS

INTRODUCTION

The overall biological problems associated with the disposal of radioactive waste in the deep oceans and the general questions which need to be addressed have been reviewed previously (Rice 1978, Angel, Fasham and Rice, 1981, Park, Kester, Duedall and Ketchum 1982, GESAMP 1983, Angel 1983, 1984a, IOS 1984, Holliday 1984). The present review sets out to establish the existing biological information on the Great Meteor East site (GME). It concerns itself mainly with systematic or comprehensive sampling programmes and does not include the more isolated, and usually non-quantitative observations made by the older expeditions like, for example, the "Challenger" and those of Prince Albert I of Monaco. The review is constrained as far as possible to a restricted area (Fig. 1), although to acquire any background information at all it has often been necessary to go further afield.

THE PELAGIC ECOSYSTEM

Systematic pelagic sampling in the GME area has been carried out mainly by German biologists from R.V. "Meteor" and by NIO (later IOS) biologists from "Discovery II" and RRS "Discovery". Since the work done by these two groups is broadly different it can conveniently be considered under nationalistic headings.

German Research

Biological investigations were carried out on and around the Great Meteor Seamount (ca. 30°00'N 28°20'W) during the 'Atlantic Seamount' cruises of RV "Meteor" in 1967. The objects of the cruises were to study the fauna of the seamounts (including Josephine Bank off Portugal), their influence on the diel migration of the deep scattering layers, and the relationships between neustonic and shallow living plankton. The nets used were small consisting of Nansen closing nets (mouth area 70cm, mesh 55μm), a modified high speed HAI sampler, Helgoland larval nets, neutson nets and Beyer's epibenthic net (mouth area 50cm, mesh 500μm). The maximum depth fished was 900m, but most of the hauls were considerably shallower, many of them being neustonic (i.e. sampling the surface 50cm of the water column). General accounts of the aims and sampling procedures of the cruises were given by Hempel (1970) and by Kinzer and Hempel (1970).

The distributions of various groups of neustonic plankton have been described from these seamount cruises and from subsequent "Meteor" cruises in the same area. Pontellid copepods have been analysed by Weikert (1973, 1975), ostracods by Moguilevsky and Angel (1975), general invertebrates and fish larvae by Weikert (1972) and Hempel and Weikert (1972), fish - including dietary analyses, by Hartmann (1970) and by John (1973, 1979).

Within the water column, Kinzer (1969) analysed the planktonic groups in and around the deep scattering layer (DSL). He found that plankton was concentrated in the DSL, at a depth of 450 to 600m, and comprised mainly copepods, euphausiids, amphipods, ostracods and chaetognaths. Buckmann and Kapp (1973) studied the distributions of appendicularians and chaetognaths between 900m and the surface. Appendicularians were common in the upper 100m and patchily distributed, but chaetognaths were poorly sampled. Nellen (1973) analysed fish larvae caught between 200 and 0m; these included species which are much deeper living as adults, e.g. Cyclothone, Chauliodus, and Vinciguerria. Ehrich and John (1973) found that the larvae of the fish Macrorhamphosus were neustonic; their juveniles had a marked reverse vertical migration - occurring at the surface by day and at 200m by night, whereas the adults lived on the bottom on top of the seamount (depth ca. 300m). Weigmann (1974) analysed euphausiids caught over the seamount and from deeper water to the south-west. She found that the euphausiid population above the seamount was depauperate compared to the surrounding ocean, and that there was no relationship between the euphausiids of the seamount and those of the West African shelf. Malacostracan larvae, of both benthic and pelagic animals, were analysed by Rice and Williamson (1977), and Kotthaus (1972) listed meso- and bathypelagic fish taken between 1000-0m with an Isaacs-Kidd trawl.

On top of the Great Meteor Seamount, Hestagen (1970) found that the near bottom plankton was more abundant by day than by night - because of diel migrations. He suggested that plankton from nearby deep water could migrate upwards towards the surface at night, be carried onto the plateau of the seamount by surface currents, and then be trapped at shallow depths as it migrated downwards.

Finally planktonic foraminifera, radiolarians, coccoliths, and pteropods have been found in cores taken both on the seamount and in adjacent deep water (Stackelberg, Rad and Zobel 1976).

United Kingdom Research

In 1960 biologists at the National Institute of Oceanography (now IOS) planned a sampling programme to study in as much detail as possible the distributions, populations and energetics of a small area of ocean. It was intended to sample this area repeatedly over different seasons and years and a position was chosen where, it was hoped, a "relatively steady state would be found". This position was 30°N 23°W, and the following year a grid of stations was established extending between 30°27'-29°33'N and 23°31'-22°29'N.

During 1961 and 1962 this grid was extensively sampled. Plankton was taken with a variety of nets but most systematically with vertically hauled closing N70 nets (mouth area $70cm^2$, mesh size 0.23mm). These were fished to a depth of 5000m, albeit in coarse (1000m) depth bands. Micronekton was caught with Isaccs-Kidd trawls equipped with a catch-dividing bucket (Foxton 1963). Samples were taken at 200m depth intervals to a depth of 800m and oblique (non-closing) hauls made between 1000m and the surface. Phytoplankton and chlorophyll samples were taken, together with water samples and bathythermograph observations to establish the physical structure of the water column.

Unfortunately the arrival of a new ship ("Discovery") and the subsequent Indian Ocean cruises, coupled with staff changes and rapid developments in sampling technology, caused a change in emphasis in the biological work at NIO and very little of this grid data was published.

Two of the deep N70 series (plus a third earlier series from 32°29'N 20°09'W) were analysed by Grice and Hulsemann (1965). They found that plankton was very scarce below a depth of 1000m and that copepods occurred at densities of less than 1 animal per m^3 of water at all depths below 1500m. Many new species and genera of copepods were described (Hulsemann and Grice 1963, Grice and Hulsemann 1965). Alexander (1965) analysed the amphipods from N70V hauls made between 200m and the surface, and Vinogradov (1968) published the volumes of two of the N70V series. Harrisson (1967) analysed the fish from day and night hauls made with the Isaacs-Kidd between 1000 and 0m and found that some fish undertook a vertical migration of up to 800m at night.

Most of the unpublished data at IOS concerns the micronekton; individual groups were counted and volumed from the Isaacs-Kidd samples, euphausiids were completely identified to species and less complete analyses were made of the cephalopods. The volumes of all of the N70V series were measured and the patchy distribution of chaetognaths within the upper 100m was examined. The peak chlorophyll content occurred in the thermocline between 50 and 100m depth and the 1% light level lay at around 150m.

IOS biologists returned to 30°N 23°W in 1972 as part of their latitudinal transect of the NE Atlantic (David 1972). A series of comparable day/night hauls were made with the acoustically controlled, opening and closing RMT 1+8 trawl (Baker, Clarke and Harris 1973). Sixteen strata were sampled by both day and night: 0-10m, 10-25m, 25-50m, 50-100m, 100-200m, 200-300m, 300-400m, 400-500m, 500-600m, 600-700m, 700-800m, 800-900m, 900-1000m, 1000-1250m, 1250-1500m, 1500-2000m. In addition a haul was made between 2000-3000m by day. (Angel 1979a) analysed the ostracods from this series and Badcock and Merrett (1976) the fish. The latter observed that 2 species of fish, Notoscopelus resplendens and Ceratoscopelus warmingi migrated well over 1000m upwards at night. Angel and Fasham (1975) and Fasham and Angel (1975) considered the zoogeography of ostracods in the N E Atlantic and included data from this series, as did Badcock and Merrett (1977) for fish and Fasham and Foxton (1979) for decapods. Unpublished data on the vertical distributions of mysids, siphonophores, euphausiids and chaetognaths are available at IOS. In addition to the vertical series, a series of hauls was made at a depth of 250m over a 24h period. From this 24h series Roe (1974) analysed the vertical migration patterns of fish, decapods, siphonophores, copepods, ostracods, amphipods, euphausiids and chaetognaths; and Foxton and Roe (1974) and Merrett and Roe (1974) described the feeding of, respectively, mesopelagic decapods and fish. This 1972 cruise provided the most comprehensive data set for plankton and micronekton which currently exists for the GME area.

In 1973 a combined physical and biological transect was made across the north Atlantic at 32°N from 16°W to 60°W (Swallow and David 1973). Twelve oblique hauls were made between 0 and 1000m with the RMT 1+8, of which numbers 2-5 were closest to GME. (No. 2 was fished at 32°06'N 20°26'W), No. 3 at 32°11'N 23°49'W, No. 4 at 32°01'N 27°12'W and No. 5 at 32°00'N 34°22'W). The distributions of siphonophores (Pugh 1975), ostracods (Angel 1979a) and euphausiids (James 1983) have been published and data on mysids, decapods and fish are available at IOS. Apart from their immediate local relevance these transect data also have important implications concerning the wider applicability of results obtained at GME. These implications are discussed later.

Similar importance can be attached to the recent joint physical/biological cruises to the permanent frontal system S W of the Azores (Angel 1981a,b, Fasham 1981, Gould 1982). This front marks the eastward extension of the southern branch of the Gulf Stream recirculation (Gould 1985), and, at the surveyed position (ca. 33°N 33°W), separates the warm Sargasso Sea water mass (Western Atlantic Water, WAW) from the colder Eastern Atlantic Water (EAW). Phytoplankton, chlorophyll a and nutrient levels were measured; the deep chlorophyll maximum was shallower and of greater magnitude in EAW than in WAW and primary productivity was probably higher (Fasham, Platt, Irwin and Jones 1985). Comparable day/night samples were made with the RMT 1+8M (Roe and Shale 1979) to a depth of 1700m, and analyses of decapods, mysids, euphausiids, fish, siphonophores, ostracods and pteropods are proceeding at IOS. Generally speaking the populations of most groups are more abundant in EAW than in WAW although pteropods and shallow living ostracods show an opposite trend. Several species of decapods migrated upwards at night from depths of at least 1400m and one fish, C. warmingi migrated from 1700m to between 100m and the surface. Concentrations of the naturally occurring radionuclide Po^{210} were measured in several species of fish and decapods (Cherry and Heyraud 1982) and extremely high levels were found in the penaeid decapods Gennadas and Bentheogennema. In addition to the frontal hauls a single tow was made just above the sea bed at a depth of 3000m at ca. 35°N 33°W; several new species and genera of copepods were described from this tow (Boxshall 1983).

Finally, and providing a link between the pelagic and benthic ecosystems at GME, pelagic holothurians have been photographed between 0 and 17m above the sea bed and a single specimen of Scotothuria herringi caught between 3600 and 3900m above the sea bed (Billett, Hansen and Huggett, in press).

Other Research

Russian data from the tropical Atlantic to the S W and S E of GME (Jaschnov 1961, 1962) show a sharp decline in planktonic biomass below a depth of 1000m, with very low values between 2000 and 5000m. These data show general agreement with those of Grice and Hulsemann (1965) and Vinogradov (1968).

In addition to the intensive sampling programmes outlined above there are many more sporadic observations from the GME area. Several IOS cruises have made occasional midwater and benthic hauls there (e.g. Herring 1983) and various geographic analyses have been made incorporating samples taken in the general area e.g. Be and Tolderlund (1971) - foraminifera, Be, Forns and Roels (1971) - general plankton, Fleminger (1973), Fleminger and Hulsemann (1973, 1974) - copepods, Ebeling (1967) and Backus, Craddock, Haedrich and Robison (1977) - fish. Many other general distribution charts encompassing GME can be found in van der Spoel and Heyman (1983). To conclude, there are even collections of copepods and ostracods taken by the French bathysphere "Archimede", which dived to depths of up to 2650m at a position ca. 37°N, 25°W (Gaudy 1972, Paulsen 1972).

THE BENTHIC ECOSYSTEM

Compared to the pelagic situation there are extremely few benthic data of immediate relevance to GME. Indeed the biology section of the SANDIA report (Auffret, Buckley, Laine, Schuttenhelm, Searle and Shephard 1984) referred only to animals and tracks seen on photographs.

On the 'Atlantic Seamount' cruises benthic samples were taken on the Great Meteor Seamount with dredges, grabs and Agassiz trawls (Thiel 1970). Except for a single grab at 1280m all the samples were shallower than 850m. Maul (1976) and Ehrich (1977) analysed the benthic fish. The latter author found that the fish fauna of the seamount was more similar to that of the African shelf between Gibraltar and Cap Blanc than to that of Madeira or the Canary Islands. Bartsch (1973a,b,c) described the mites (Acari), Grasshoff (1972a,b, 1973, 1977) the gorgonians and Hartmann-Schröder (1979) the polychaetes.

There are few papers describing specific groups of animals from deeper water around the seamount or at GME. Keller (1984), Mironov and Sagaidachny (1984) and Galkin and Kerovchinsky (1984) described deep water corals, echinoids (Echinocyamus), and brisingiid asteroids (Freyella) respectively. Billett, Hansen and Huggett (in press) analysed pelagic holothurians caught on the abyssal plain at GME and adjacent sites with an otter trawl (Merrett and Marshall 1980) and the I.O.S. epibenthic sledge (Aldred, Thurston, Rice and Morley 1976, Rice, Aldred, Darlington and Wild 1982). Huggett (in prep.) has used a wide angle survey camera at GME which photographs an 80m^2 area of sea bed from a height of 10m above it. He observed that the densities of some benthic animals are surprisingly high - which contrasts with the low biomass measurements recorded by more general faunistic surveys of the area. Weaver and Schultheiss (1983) found that cores taken from depths of 5444 to 6129m in the GME area contained open burrows. One of these burrows had an organic lining, suggesting that recent polychaetes or pogonophorans could be responsible for their formation.

More general benthic studies from the deep water around GME are as scarce as these more specific analyses. Kuznetsov (1960) surveyed the benthic fauna along 30°W between ca. 25°S and 50°N and found very low biomasses between 20 and 30°N. Monniot and Segonzac (1984) established a number of stations between 44°N 17°W and 32°N 21°W and sampled these with a beam trawl, an epibenthic sledge and a Reineck corer. They analysed the densities of various groups and concluded that the centre of the Madeira basin (ca. 32°N 21°W) had a poorer fauna than the more northerly basins. Although detailed identifications and biomass measurements were not made, this study is the best analysis of the abyssal fauna at GME which is currently available.

More comprehensive studies have been made to the south west and west of GME. Khripounoff, Desbruyeres and Chardy (1980) analysed the energy budget of small macrofauna taken with a corer at the Vema fracture zone (depth 5100m, position 11°N 44°W). Sibuet, Monniot, Desbruyeres, Dinet, Khripounoff, Rowe and Segonzac (1984) established 2 stations, one at the foot of the Amazon cone (ca. 8°N 49°W), the other west of the Vema fracture zone (ca. 10°20'N 46°48'W). They measured flux rates of organic material with sediment traps, the organic composition of the sediment, and the densities, distributions and biomasses of several taxa caught with a box core and beam trawl. Considerable differences in the populations at the 2 sites were found, which were correlated with differences in available food. French scientists have also examined the fauna and sediment composition at 2 stations in the Cape Verde Basin (ca. 19-25°N, 25-29°W). The results have not yet been published but at least the megafauna taken in the trawls was very poor.

Most of the work to the west of GME involves transects from the coast of the USA and the Caribbean. Within these transects there are some quantitative and qualitative data from Bermuda (e.g. Sanders, Hessler and Hampson 1965, Rowe, Polloni and Horner 1974) and the former authors also present results obtained with an anchor dredge in the Sargasso Sea and from between ca. 7-9°N 34-54°W.

Most of the IOS benthic biological work in the subtropical Atlantic has been done to the east and south east of GME (ca. 21-31°N, 17-22°W). General quantitative estimates of a number of benthic groups have been made (Rice, Aldred, Billett and Thurston 1979) and specific studies made on a deep-sea anemone, Actinoscyphia aurelia (Aldred, Riemann-Zürneck, Thiel and Rice 1979), Xenophyophores (Tendal and Gooday 1981, Gooday and Nott 1982, Gooday 1983a), Foraminifera (Gooday and Haynes 1983, Gooday 1983b), and the fauna inhabiting or encrusting foraminiferan tests (Gooday 1984, Gooday and Cook 1984). The ecology of benthic and benthopelagic fish has been examined from a rather wider area (8-34°N, 11-30°W) by Marshall and Merrett (1977), Merrett and Marshall (1980) and Merrett and Domanski (in press).

Many aspects of deep-sea biology, especially of benthic animals, have recently been reviewed (Rowe 1983a and enclosed papers). Much of the information contained in this volume has general or direct relevance to the benthic ecosystem at GME.

ZOOGEOGRAPHIC CONTEXT OF GME

The distributions of most oceanic animals are influenced by hydrography over large areas and by patchiness on a more local scale. Faunistic differences across hydrographic frontal or transition zones may be distinct in terms of the presence or absence of species, or may be more gradual in terms of changing abundances. Both differences result in changes in community structure. Van der Spoel and Pierrot-Bults (1979) and van der Spoel and Heyman (1983) present recent syntheses of planktonic zoogeography.

Epipelagic organisms tend to be most restricted by hydrographic boundaries. Mesopelagic and epipelagic communities are inextricably linked by vertical migrations - which may be daily, seasonal or ontogenetic. Consequently hydrographic effects are also evident in mesopelagic distributions but their intensity decreases with depth - so that bathypelagic (below 2000m) animals tend to be cosmopolitan. It should however, be borne in mind that most oceanic zoogeography has been done on epipelagic or shallow living animals and there is a progressive decline in information with increasing depth.

The zoogeographic studies most relevant to the GME site are those of Backus *et al* (1977), who analysed the distributions of myctophid fish between 800m and the surface, and those resulting from the IOS latitudinal transects (Angel and Fasham 1975, Fasham and Angel 1975, Badcock and Merrett 1977, Fasham and Foxton 1979), the longitudinal transect across 32°N (Pugh 1975, Angel 1979, James 1983) and the data resulting from the Azores Front cruises (Gould 1985, Fasham, Platt, Irwin and Jones 1985).

GME is situated within the North Atlantic Subtropical region of Backus *et al*

(1977). They described this region as bounded to the north (ca. 35°N) by the N. Atlantic Temperate region and to the south (ca. 18°N) by the Atlantic Tropical region. The northern boundary of Backus et al (1977) at ca 35°N has not been found in the IOS latitudinal transect, but there is a transition zone further north between ca 40-53°N separating a northern area of seasonal thermal stratification and deep winter mixing from a southerly area of semi-permanent thermal stratification (Fasham and Foxton 1979, Angel 1984b). The southern boundary of Backus et al (1977) was based upon the change over between northern and southern Atlantic central water masses (NACW and SACW). Fasham and Angel (1975) and Fasham and Foxton (1979) found a boundary below a depth of ca. 500m at ca. 18°N but concluded that this was due to the northern limit of the Antarctic Intermediate Water (AIW).

Longitudinally Backus et al's (1977) region extends from the west African coast to the Caribbean, but a distinct upwelling fauna exists off Mauritania which probably extends further north up the African coast (Angel 1979b). The GME area is influenced by Mediterranean water between ca. 750-1300m (Badcock and Merrett 1976, Saunders 1983) but Fasham and Angel (1975) were unable to find specific faunal associations with this.

Backus et al (1977) subdivided their subtropical region into quadrants by an E-W boundary marking the subtropical convergence and a N-S boundary marking the eastwards limit of Sargasso Sea water. Their subtropical convergence runs approximately through the GME position and they found significantly more myctophids to the north of the convergence than to the south. The position of the subtropical convergence is not, however, well defined in the eastern North Atlantic (Fasham and Foxton 1979), and it has not been identified as a faunal boundary in any of the IOS transects (Angel and Fasham 1975, Fasham and Angel 1975, Badcock and Merrett 1977, Fasham and Foxton 1979).

Backus et al's north-south boundary at ca. 40°W corresponds to the eastern and western Atlantic water either side of the Azores Front (see p. 11). Faunistic differences across this front were analysed from the E W transect of "Discovery" across 32°N. The observed differences vary with the group - ostracods showing only gradual, clinal, changes in community structure from east to west (Angel

1979a), whereas siphonophores (Pugh 1975) and euphausiids (James 1983) show more marked differences. The same front was studied on the Azores Front cruises of 1981 and again the effect of the front varies with the different groups (see p.11).

The Azores Front is probably continuous with a meandering front observed further east at ca. 36-32°N 18-24°W (Käse and Siedler 1982, Gould 1985, Siedler, Zenk and Emery in press). Eastern Atlantic Water occurs to the north of both the Azores front and this eastern front, but the bulk of Western Atlantic Water only extends east to about 30°W (Gould 1985). Consequently GME is probably to the east of Western Atlantic Water but also to the south of Eastern Atlantic Water. The water mass structure changes markedly between 35 and 20°W (Gould 1985) and the detailed hydrography of the area is not yet clear.

GME is therefore enclosed by hydrographic and/or faunistic boundaries of which the closest are those marking the eastwards limit of Western Atlantic Water and the southern limit of Eastern Atlantic Water. With the probable exception of the upwelling area off West Africa, the faunal differences across the adjacent boundaries are mostly ones of detail or gradual change and the distributions and community structures at GME are probably similar to those found elsewhere in the subtropical Atlantic. If a wider east/west scenario is applicable to GME then data from this site can be compared with long term data from station S off Bermuda (32°N 64°W) - see, for example, Deevey (1971), Deevey and Brooks (1971, 1977), Deuser (1984), and from the associated Ocean Acre (Gibbs and Roper 1970, Donaldson 1975). To the east there is an extensive data set taken off Fuerteventura (ca. 28°N 14°W) during the SOND Cruise (RRS Discovery SOND Cruise 1965; Collected Papers 1980). It should be noted however that the applicability of SOND data to GME probably varies with the group - Angel (1969, 1979a) found few differences in the ostracods but the second most abundant fish at 30°N 23°W (Cyclothone microdon) was completely absent at Fuerteventura (Badcock 1970, Badcock and Merrett 1976). North/south data from sites adjacent to GME are available from the IOS latitudinal transect. Comparable day/night series were fished from 0 to 1250m and from 1000 to 2000m at 18°N 25°W (David 1970, 1972) and from 0 to 2500m at 40°N 20°W (David 1971). In addition to the zoogeographic references quoted previously, Foxton (1972) analysed the decapods from this transect and unpublished data for other groups are available at IOS.

The previous discussion concerns, at most, the upper 2000m of the water column and there are no comparable bathypelagic data. However, the low volumes and densities of bathypelagic plankton at GME (Grice and Hulsemann 1965, Vinogradov 1968) agree with the more widespread observations of Jaschnov (1961, 1962) and Angel and Baker (1982). Given the general cosmopolitan nature of bathypelagic faunas there is no reason to suppose that the situation at GME will be signficantly different from that observed elsewhere in the N E Atlantic. Angel and Baker (1982) analysed the distributions of plankton and micronekton to depths of 4500m at three sites in the N E Atlantic (20°N 21°W; 42°N 17°W and 49°40'N 17°W). They found that the biomass of both plankton and micronekton decreased exponentially with depth, and in a similar manner, at all 3 positions.

The decline in midwater biomass is arrested just above the sea bed, (ie within 100m), where there is an increase in biomass and in the numbers of individual species or groups (Wishner 1980a,b, Boxshall and Roe 1980). Many planktonic species are endemic to this near bottom zone (Grice and Hulsemann 1970, Grice 1972, Roe in prep.). The increased biomass in this zone presumably reflects a greater availability of food and the abundances of bacteria (Karl, La Rock, Morse and Sturges 1976) and particulates (e.g. Honjo 1978) increase here. Direct evidence that the near bottom layer is an area of relatively high biological activity has been obtained by in situ measurements of respiration and excretion rates (Smith 1982) and grazing rates (Wishner and Meise-Munns 1984). Some of these near bottom observations were made at 20°N 21°W - and therefore reasonably close to GME (Boxshall and Roe 1980, Roe in prep.), but all of them are expected to apply to the GME site.

Similarly, many of the conclusions reached in previous deep-sea benthic work are probably applicable to GME - despite the dearth of detailed information on the abyssal fauna at this site. Low biomass (see, for example Rowe 1983b) and high density (Hessler and Sanders 1967) can be expected, although both are known to vary both regionally and bathymetrically (Rowe 1983b, Rex 1983). The causes of high diversity in deep-sea benthic communities are not completely understood and values for abyssal fauna may be lower than those at intermediate and slope depths (Rex 1983). The generally ubiquitous nature of abyssal animals suggests that the species living at GME are likely to be the same as those found at comparable depths elsewhere in the subtropical or temperate Atlantic.

CONCLUSIONS

As with most other oceanic areas the biology of GME is best known in the upper 1000m of the water column. However, even with this zone there is very little direct information on the phytoplankton and primary productivity. From depths below 2000m the only quantitative data are a few measurements of copepod and plankton abundances (Grice and Hulsemann 1965, Vinogradov 1968), and the only systematic qualitative data are for calanoid copepods (Grice and Hulsemann 1965). There are virtually no direct benthic data and none at all on the crucial midwater/benthic interface just above the ocean floor.

At GME the food supply for the water column and benthos is derived from photosynthesis in the euphotic zone. The downward flux resulting from this primary production - in the form of dead cells, particulates, faecal pellets from herbivores and then carnivores, depends upon the amount of initial production; ultimately the biomasses of the midwater and benthic communities also depend upon this. The net flux through the water colum is downwards, and in addition to providing food for deeper living communities the "rain" of particles may directly scavenge radionuclides from the water and thus carry them down (see, for example, Angel 1984a).

A basic requirement for any biological assessment of GME is therefore a detailed quantitative and qualitative analysis of the fauna and an estimate of the initial primary production. Quantitative data provide information on the amounts of material at various depths - and consequently an indication of likely flux. Qualitative data provide information on species' occurrence - and their likely role in any material transport can then be evaluated directly or in the light of existing knowledge. Initial exposure to radionuclides deposited in or on the sea bed will be to the benthic community. It is particularly important that this community, and the associated near-bottom pelagic community, should be examined in as much detail as possible - including analyses of feeding interactions and reproductive strategies.

Any upward flux from the sea bed will be going against biomass gradients. Active transport will depend upon vertical migrations - which may be diurnal, seasonal, ontogenetic or sporadic. The latter are very difficult to detect or quantify. Material may be transported upwards by animals feeding, either on other animals or on particulates or detritus, and then subsequently migrating to shallower depths (e.g. Roe 1984a). Regular diurnal migrations of plankton are probably not significant at depths below 1000m (Angel, Hargreaves, Kirkpatrick, and Domanski 1982) but some of the micronekton at GME do migrate towards the surface from depths of 1400-1700m. It is therefore important to determine the distributions of these and related species to assess their likely importance.

Bathypelagic feeding probably involves considerable recycling of material (Pearcy and Stuiver 1983) and may not depend upon direct feeding in the upper water layers. However, some benthic fish (e.g. Coryphaenoides spp) have been caught over 1400m above the sea bed, and the stomachs of these and similar fish sometimes contain signficant quantities of midwater animals (see for e.g. Haedrich 1974, Haedrich and Henderson 1974, Pearcy and Ambler 1974, Marshall and Merrett 1977). Other benthic animals have been caught in midwater, some of them several thousand metres off the bottom (McGowan 1974, Angel 1984a, Billett et al In Press). It is very unlikely that such events are a significant feature of the ecosystem at GME but the possibility has to be investigated. It may be that pelagic feeding (or transport) by benthic fish will be of greater importance on the continental slope. Most of the fish in which midwater feeding has been suggested are slope dwellers (Haedrich and Henderson 1974, Pearcy and Ambler 1974, Marshall and Merrett 1977) and if there is horizontal transport across the abyssal plain to an adjacent slope (West Africa, Madeira and the Canary Islands) then benthic/midwater migrations may be important. However, calculations (GESAMP 1983) indicate that horizontal transport by fish will probably be much less than any due to water movements, and analysis of slope fishes off West Africa (Merrett and Marshall 1980) show that few species have depth ranges extending from the abyssal plain to less than 2000m.

It is appropriate to note here that there are two local fisheries which may be influenced by direct upward transport of material through the water column. There is a deep line fishery off Madeira for the scabbard fish Aphanopus carbo. This species is caught during the night in midwater at depths of ca 500-1100m but may live and feed on the bottom by day - at depths of ca 1500m (Harrisson 1967). Sperm whales are caught off the Azores, and until very recently were also taken off Madeira. Sperm whales dive to depths of at least 1200m, and perhaps much deeper (Clarke 1980), and they feed at least partially on the bottom (Roe 1969, Clarke 1980). A direct transfer of Co^{60} from mesopelagic squid to the surface via these whales has recently been demostrated by Umeza, Ebihara, Minamisako and Watanabe (1984).

Many benthic animals have pelagic eggs and larvae, and the larvae of bathy- and mesopelagic animals often live at shallower depths than the adults. Both strategies have been found on and around Great Meteor Seamount, and GESAMP (1983) suggested that concentrated release of reproductive products could be a relatively important way of biologically transporting contaminants. The occurrence of pelagic and shallow-living larvae over the abyssal plain at GME should be investigated.

The accompanying sampling programme aims to provide quantitative and qualitative data on the fauna at GME. In particular it is intended to: -

1. Estimate the daily primary production.
2. Study the distributions and abundances of midwater animals between the surface and the sea bed.
3. Estimate the biomass of the total water column and the contributions of the various taxa to it.
4. Examine the interrelationships between the pelagic near bottom fauna and the midwater and benthic populations in terms of distributions, numbers and feeding.
5. Examine the distributions, diversity and biomass of mega- and macrobenthic animals.
6. Examine the distributions, biomasses and trophic relationships of demersal fish.
7. Examine the activities of benthic animals by time-lapse photography

(Bathysnap - see below).

This sampling programme will provide a basic data set, but it will give no information on long or short term stability. There is very little information on stability or variability in deep-sea ecosystems. Recently physical, chemical and biological periodicity and/or seasonality has been found in the deep benthos (see Billett, Lampitt, Rice and Mantoura 1983 and the references therein). Billett and his colleagues used a time-lapse photographic system (Bathysnap - Lampitt and Burnham 1983) together with a multiple corer. Their observations were made in the temperate Atlantic but seasonal variations are apparent in sediment traps set at 3200m off Bermuda (Deuser 1985) and plankton data from the same area show considerable monthly and seasonal variations (Deevey and Brooks 1971, 1977). Roe (1984b) made a series of repeated hauls at a depth of 3500m to assess the variability of bathypelagic communities in time and space but the data are not yet analysed.

To address the problem of variability at GME a long term repeated sampling programme is required. A repeatable sampling programme is also needed to assess the likelihood of horizontal biological transport across the abyssal plain. Such repeated programmes need not necessarily be as comprehensive as the present proposal - but they should contain sufficient detail to identify major changes. Any such changes which are visually significant and occur on the bottom could be initially identified and subsequently monitored by deploying Bathysnap (Lampitt and Burnham 1983, Lampitt, Rice and Thurston 1984) over long periods.

SAMPLING PROGRAMME

For primary production and the vertical distribution of chlorophyll we intend to:

a) Make daily vertical profiles between 300 and 0m with a CTD/multisampler equipped with a photometer, fluorometer and beam transmittance meter.

b) Measure photosynthetically available surface irradiance.

c) Measure surface primary production with C^{14}.

For midwater plankton and micronekton we will use the RMT 1+8M (Roe and Shale 1979, Roe, Baker, Carson, Wild and Shale 1980) equipped with a near bottom echo sounder (Roe in prep.) for the deepest tows. We intend to:-

a) Fish 100m depth layers between 1500m and the surface by day and night.
b) Fish 200m depth layers between ca. 1500m and ca. 5100m.
c) Fish 100m depth layers between ca. 5100m and the bottom (ca. 5400m).
d) Fish depth layers of ca. 10-25m, 25-50m and 50-100m off the bottom.

Items c and d will be repeated at least three times.

For benthic sampling we will use the semi-balloon otter trawl (OTSB 14 - Merrett and Marshall 1980) and the epibenthic sledge (BN1.5 - Rice, Aldred, Darlington and Wild 1982). It is intended to make six hauls with each piece of gear.

'Bathysnap' (Lampitt and Burnham 1983) will be deployed to provide a photographic record of activity on the sea bed for a period of about one month. It is hoped to redeploy 'Bathysnap' and leave it at GME, recovering it on a subsequent cruise next spring. A long term record may provide information on variability at the site.

We will also make several CTD casts to ca. 5300m to establish the temperature and salinity structure of the water column.

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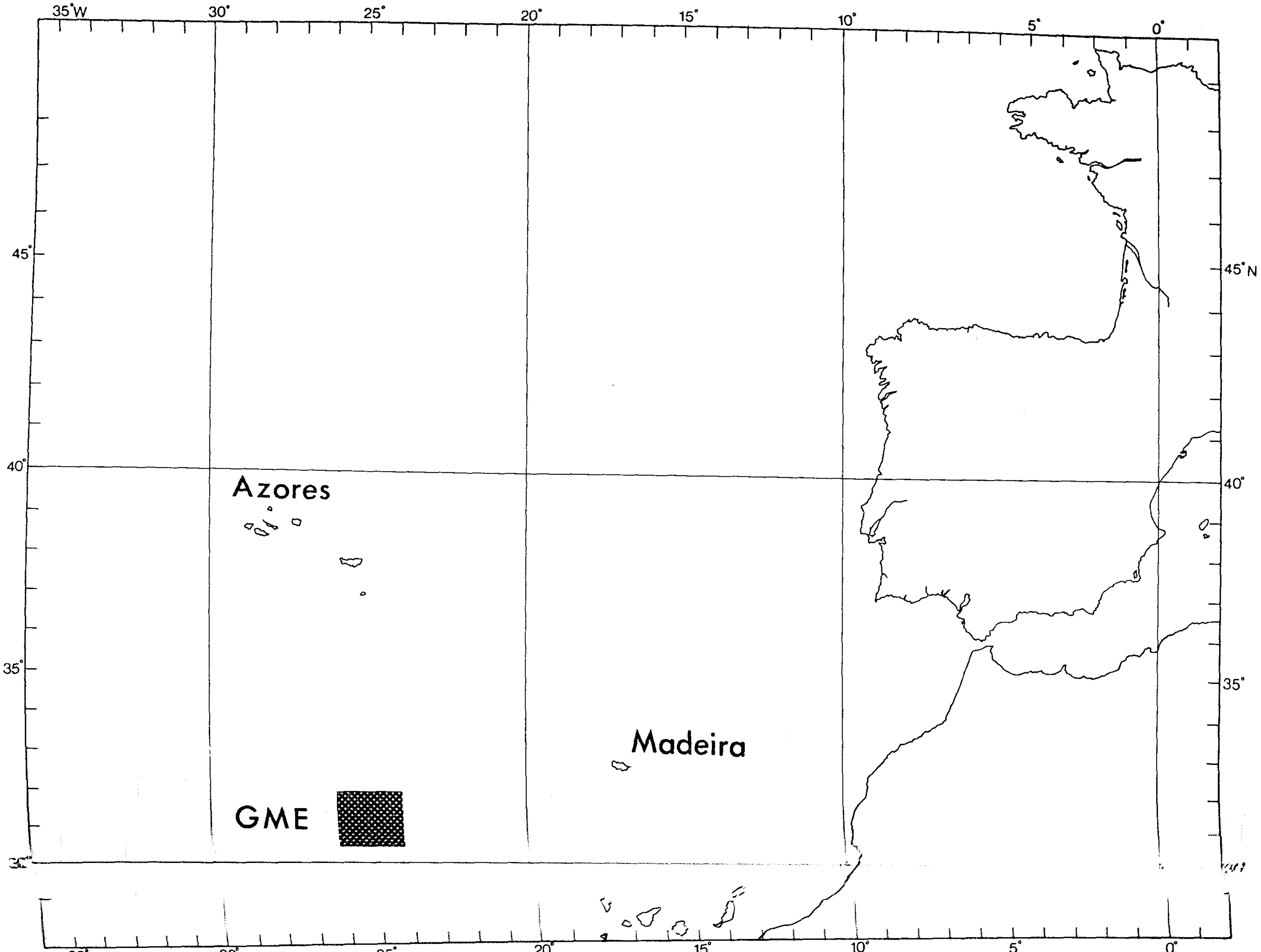

Fig 1

Location of Great Meteor East