THE PALAEONTOLOGY AND GEOCHEMISTRY OF THE GASTRIOCERAS CANCELLATUM MARINE BAND, ON THE GLYN NEATH BANK, NORTH CROP OF THE SOUTH WALES COALFIELD

by

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Summary

The Gastrioceras cancellatum Marine Band in the Namurian of the Glyn Neath Bank, near Glyn Neath on the North Crop of the South Wales Coalfield shows twelve different palaeontological phases and three geochemical phases within 250cm of shale above the thin persistent cancellatum sandstone. The fauna, geochemistry and sedimentology of the marine band can be shown to reflect the palaeoenvironment. Phase 1 to 9 (1. *Planolites* (A); 2. *Lingula*; 3. Coarse ribbed bivalves; 4. Brachiopods and "*Hydrobia*-like" gastropods; 5. *Planolites* (B) and vertical burrows; 6. Mixed bivalves and brachiopod spat; 7. *Glabrocingulum* and *Nuculana*; 8. Solid thick-shelled goniatites, and 9. *Nuculana, Glabrocingulum* and brachiopod. "nests") indicate a gradual deepening of water; phase 10 (fragmented, thin shelled goniatites) represents a sudden deepening to an anoxic environment with slow sedimentation rates and reduced redox potentials. Phase 11 (mixed fauna) represents a rapid shallowing of the water depth to phase 12 (*Planolites* (A). The change in water depth may have been several metres to several tens of metres.

Introduction

(*a*) *Previous Research*

In a major marine band a series of faunal phases, and lithological and geochemical levels can be recognised (Robertson, 1932; Elias, 1938; Craig, 1954; Ferguson, 1962; Heptonstall, 1964; Calver, 1968; Bloxam and Thomas, 1969; Spears and Amin, 1987 and Holdsworth & Collinson, 1987). The principal work on faunal phases was done on Westphalian marine bands by Calver (1968), Namurian marine bands have similar fauna, but have been neglected. Jones (1965) discussed the nature and threefold lithological and fauna development of the Lower Gastrioceras (G1) stage marine bands, but his descriptions lacked detail. Heptonstall's (1964) study of the G. cancellatum Marine Band in Northern England concentrated on taxonomic studies neglecting its geochemistry.

These phases and levels may correspond with environmental changes in terms of cyclically fluctuating salinities, variations in water depth, sedimentation rates and energy regimes, induced by eustatic sea level changes, tectonics or other allocyclic processes (Ramsbottom, *et al.* 1962; Jones, 1963, Holdsworth, 1966; Calver, 1968; Collinson, 1987).

(*b*) *Present Study*

The Gastrioceras cancellatum Marine Band in the Namurian of the North Crop of the South Wales Coalfield is exposed along a road cutting at the "Glyn Neath Bank" (NGR.SN91450772–91510771) near Pont Nedd Fechan (Fig. 1). It was studied in order to determine the relationship between its palaeontology, geochemistry, sedimentology and thereby consider possible sea level changes, energy regimes and palaeoenvironments within a Namurian marine band.

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Techniques

(*a*) *Field sections and sample collecting*

The shale, above a persistent decimetre bed of quartz wacke locally known as the cancellatum sandstone (Jones, 1965), which contains the G. cancellatum Marine Band was examined. Four 15cm deep, 5m thick vertical excavations were made along strike over an exposure of approximately 100m. The height of any noticable changes in fauna and lithology were recorded. 2kg samples of shale were collected at intervals of 10cm in one section and 1.5kg samples at 20cm in another section.

(*b*) *Laboratory work*

The shale was dried in air and either split by hand or distintegrated using a technique developed by Knights (1951). The fossils were removed from the shale, their relative attitude to fissibility, mode of preservation and fragmentation were recorded, examined and measured under the binocular microscope, and the total number of fossils per species within the shale sample was recorded.

Each sample of shale was powdered using a jaw crusher and passed through a BSS60 (250u) sieve. The colour of each sample was recorded using the United States Geological Survey standards.

(*c*) *Chemical Analysis*

1. Uranium, Thorium and Potassium—A gamma-ray spectrometer was used to measure uranium, thorium and potassium using the method of Strachan (1973).
2. Total Organic Carbon (TOC)—The combustion products of powdered shale samples were analysed using an automatic self-integrating, steady-state, thermal conductivity analyser (Model 240C Elemental Analyser, Perkin-Elmer) to obtain the TOC content.
3. Ca, Ba, Fe, K, Rb, Zn, V, Mg, Mn, Cu, Cr, Ti, Zr, Ni and Sr—The shale samples were fused with lithium metaborate using a technique developed by Imperial College Geochemical Unit and analysed using an I.C.P. to measure major and minor elements.

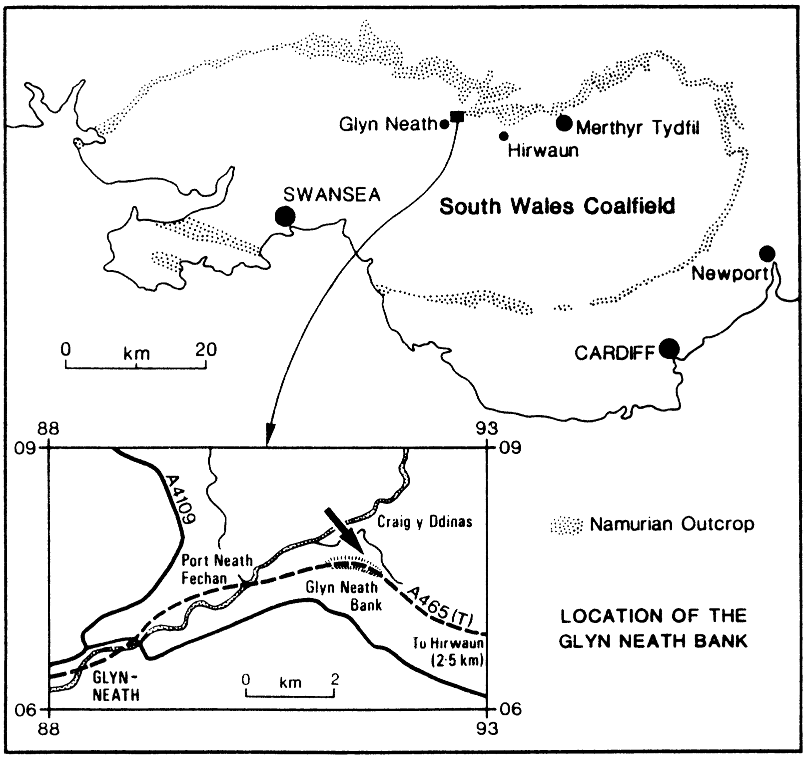

Fig. 1. Location Map.

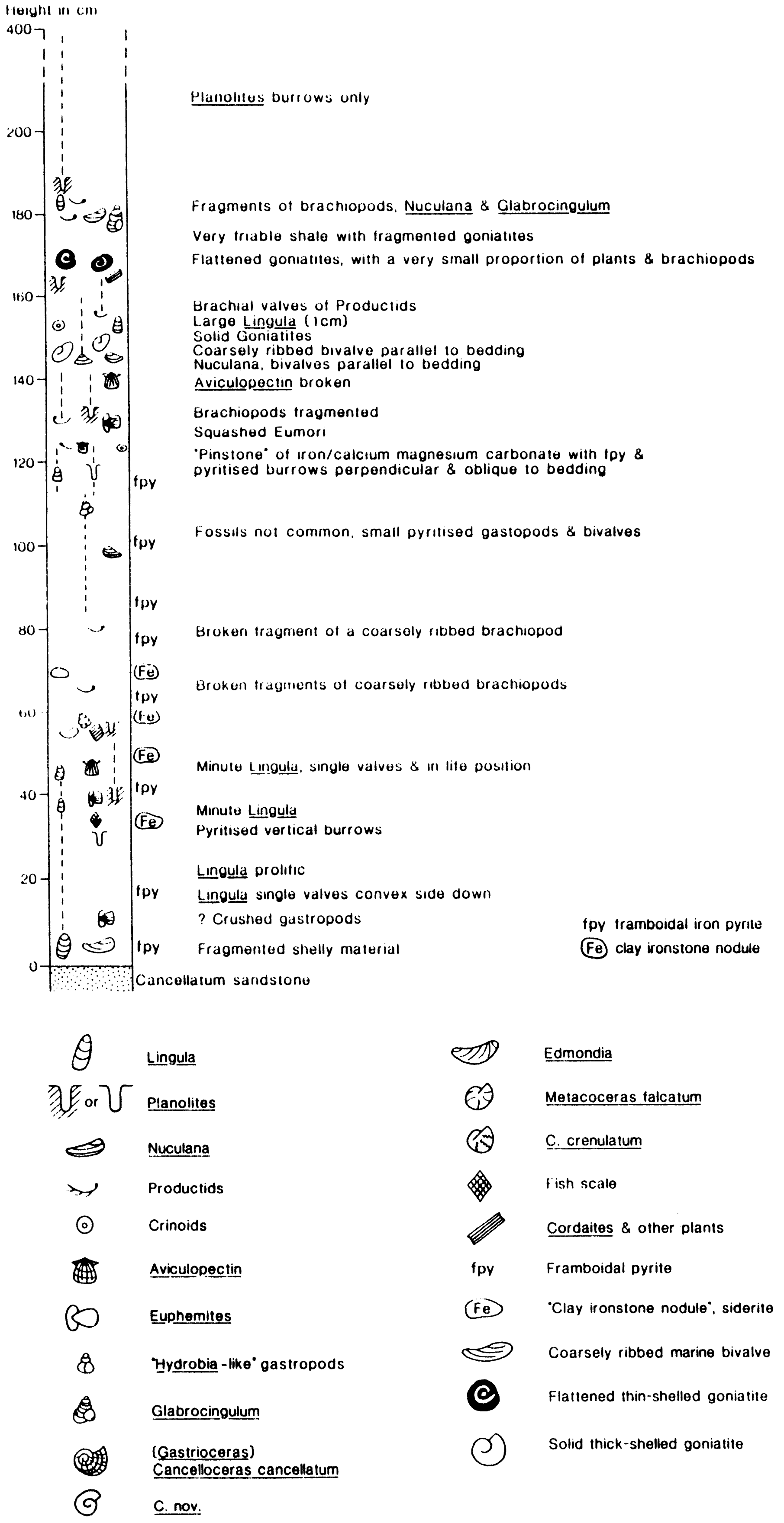

Fig. 2. Field log at (NGR SN91490771) the eastern end of the Glyn Neath Bank.

Results

(i) *Palaeontology*

Twelve faunal phases were recognised in the section, listed from the base upwards (Fig. 2 and 3);

1. *Planolites* (A) phase: These horizontal burrows have been described by many workers (Ramsbottom et al. 1962; Calver, 1968; Holdsworth, 1966 and Eager, 1985).

2. *Lingula* phase; *Lingula* is very prolific and at least 25% of the population were found in life position, vertical to the shale fissility. Figure 4 shows the size ranges for *Lingula* samples within the section.

3. Coarse ribbed bivalves phase; *Edmondia sp.*, *Sanguinolites sp.*, *Caneyella sp.*, *Palaedima simplex* and *Aviculopecten losseni* occurred as isolated valves.

4. Brachiopod and "*Hydrobia*-like" gastropods phase; Brachiopods (*Eomarginifra* aff. *frechi*) were found in life position and "*Hydrobia*-like" gastropods (cf. *Loxomena*) were very abundant.

5. *Planolites* (B) and vertical burrows phase; *Planolites* (B) was abundant and mm diametre calcite filled vertical burrows were present. Some of these may have been small foraminifera, other fossils included fragments of brachiopod and *Glabrocingulum* aff. *armstrongi.*

6. Mixed Bivalve and brachiopod spat phase; Numerous bivalves (Edmondia sp.; *Sanguinolites* sp.; *Posidonia* sp. and *Palaeolima simplex*) with brachiopod spat were present.

7. *Glabrocingulum* and *Nuculana* Phase; *Nuculana attenuata* was found in life position with well preserved specimens of *G. armstrongi.*

8. Solid thick-shelled goniatites phase; *Cancelloceras evansi, C.* aff. *crencellatum, C.* cf. *demaneti, Reticuloceras superbilinque, Anthrococeras* sp. and *Agastrioceras* were present as well preserved fossils often forming nuclei for calcareous nodules.

9. *Nuculana. Glabrocingulum* and brachiopod "nests" phase; Brachiopod "Nests" (*Eomarginifera frechi*), which had as many as 100 individual and coquinas were present with occasional *N. attenuata* and *G.* aff. *armstrongi.*

10. Fragmented thin-shelled goniatites phase; C. cancellatum, C. branneroides/C. rurae, C. cf. *crencellatum, C.* sp. nov. aff. *cancellatum* and *Anthracoceras* sp. were present with densities exceeding 100 individual Kg^{-1} and were frequently highly fragmented.

11. Mixed phase; Most of the fauna present in Phase 1 to 9 were present within this phase, but *L. mytiloides* was less common and *Orbiculoldes nitida* was present.

12. *Planolites* (A) phase; This is similar to phase 1 with an absence of marine fauna.

(ii) *Geochemistry*

Geochemically the marine band can be split into three levels (Fig. 5) Level I (0–160 cm) shows little geochemical variation throughout 160 cm of shale and is similar geochemically to Level III (200–250 cm). Level II (160–200 cm) is very distinctive having higher concentrations of TOC, U, P, Ca, Ni, Zn, Cu, U, Cr and Sr and lower concentrations and ratios of Th, Na/K, Th/U, Si/C and Ba.

(iii) *Sedimentology*

The marine band comprises shale which varies from medium dark grey to grey black, the latter being associated with Level II which is rich in organic carbon (Figs. 2 and 5). Horizons of poorly developed black grey "bullion limestone" (Holdsworth, 1966) nodules up to 10 cm thick and 30 cm long were present between 100 and

140 cm above the cancellatum sandstone. These comprise ferroan calcite and ferroan dolomite with subordinate pyrite and fine horizontal laminations were picked out by silt and clay minerals. No microfossils were seen, but well preserved goniatites and productoids with spines were commonly preserved in life position.

Below 1 m (phases 1 to 3) and in phase 12, oblate "clay ironstone" nodules up to 3 cm long were present, comprising siderite and had a high clay mineral content.

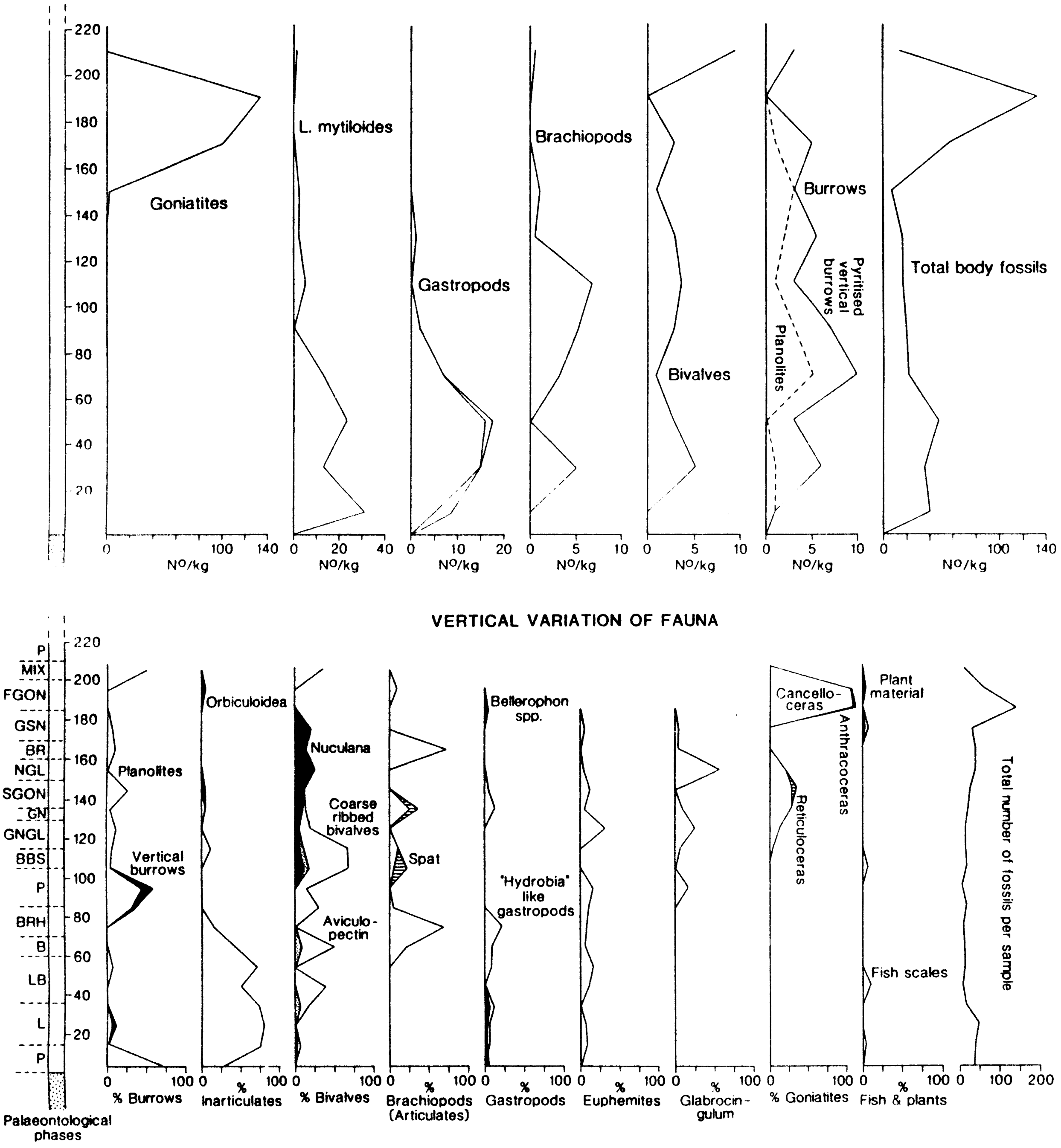

Fig. 3. Vertical distribution of fauna in two sections. P—*Planolites*. MIX—Mixed fauna; FGON—Thin-shelled flattened goniatites; GSN—Goniatites and solid *Nuculana*; BR—Productoid "nests"; NGL—*Nuculana* and *Glabrocingulum*; SGON—Sold thick-shelled goniatites; GN—Goniatites and *Nuculana*; GNGL—Goniatites, *Nuculana* and *Glabrocingulum*; BBS Bivalves and brachiopod spat; BRH, Brachiopods and "*Hydrobia*-like" gastropods, B—bivalve; LB—Bivalves and *Lingula*; L—*Lingula*.

Faunal Phases: 1. *Planolites* A (P); 2. *Lingula* (L); 3. Coarse-ribbed bivalves (LB); 4. Brachiopods and "*Hydrobia*-like" gastropods (BRH and B); 5. *Planolites* B and vertical burrows (P); 6. Mixed bivalve and brachiopod spat (BBS); 7. *Glabrocingulum* and *Nuculana* (GN and GNGL); 8. Solid thick-shelled goniatites (SGON); 9. *Nuculana, blabrocingulum* and brachiopod nests (BR and NGL); Fragmented thin-shelled goniatites (FGON and GSN); 11. Mixed (MIX) and 12. Planolites A (P).

Discussion

Various authors (Elias, 1938; Craig, 1954; Ferguson, 1962; Heptonstall, 1964; Calver, 1968, and Spears and Amin, 1981) have shown how faunal phases relate to palaeoenvironment. Similarly the fauna in Gastrioceras cancellatum Marine Band reflects changes in the palaeoenvironment, plus the geochemistry can be related to these changes.

The geochemistry of phases 1 to 9 (Level I) changes little and possibly indicates a geochemical environment which had little influence on the faunal development and was controlled little by water depth (Fig. 5). The fauna however does indicate a slight progressive deepening of water up section (Fig. 6) *Planolites* (A) phase (1) represents brackish water burrows (Ramsbottom *et al.*, 1962; Holdsworth, 1966; Calver, 1968; Eager et al., 1985 and Pollard, 1986). The presence of siderite rich clay ironstone nodules within phases 1 to 3 (Fig. 2) indicate shallow water environments such as are present on contemporary deltas and lakes (Pye, 1984).

Lingula Phase (2) probably indicates a quasi-marine environment, though living species e.g. *L. unguis* can tolerate a wide-range of conditions from intertidal zones, tidal channels, shallow marine environments and flourish near outlets of major rivers (Ferguson, 1963 and Craig, 1952). A gradual decrease in the size of individuals in samples taken from up the section to a height of 80 cm where larger forms with smaller populations take over may be a function of deepening of water and increased salinites producing environmental stunting and giantism (Hallam, 1965) (Fig. 4). The width and length histograms are skewed towards smaller individuals (Fig. 4). The frequent numbers of *Lingula* preserved in life position indicates that this does not represent a death assemblage (Boucot, 1957). It may represent a high infant mortality, but the vertical differentiation in size of individuals up the section suggests that this is not the case and may represent two populations. Although four species of *Lingula* have been recovered from the Namurian of Western Europe (viz. *L. parallela. L. squamiformis, L. credneri* and *L. mytiloides*) each distinguished by characteristic length/width ratios in the Gastrioceras subcrenatum Marine Band on the North Crop. Therefore it is likely that there are two populations of *Lingula* within the section and size changes of samples may be a function of water depth.

The coarse ribbed bivalve phase (3) suggests an environment with slightly higher energies than the two preceding, because *Edmondia* sp. *Sanguinolites* sp. and *Caneyella* sp. were likely to have been byssally attached and their strong heavy shells would be more resistant to higher energies.

The presence of brachiopods in Phase 4 is the first real evidence for normal marine salinities. This Phase is followed by a second *Planolites* phase (Phase 5) with vertical burrowers. *Planolites* in Phase 5 may have been a different organism and need not be associated with the brackish water forms in phase 1 (Crimes, 1976). Mixed bivalves dominate in Phase 6 suggesting a distinct community. Phase 7 contains *N. attenuata* preserved in life position suggesting deeper water than the preceding phases (Fig. 6) (Calver, 1968).

Namurian goniatites can be divided into two broad types, "thick-shelled" and "thin-shelled" (Calver, 1968). Ramsbottom *et al* (1962) suggested that thin-shelled goniatites are deeper water forms than the thick-shelled goniatites and Swan (pers. comm.) believes that many of the thick-shelled forms were benthonic. The difference between the goniatites in Phase 8 and those in Phase 10, maybe that Phase 10 represents the deeper water thin-shelled free living forms. A phase, rich in brachiopod nests (Phase 9) separates the thick shelled benthonic goniatite community from deeper water forms of Phase 10.

Phase 10 marks a major change in the geochemistry of the shales and the introduction of deep water forms (Ramsbottom *et al* 1962 and Calver, 1968) (Figs. 5 and 6). The ratio of thorium/uranium is lowest in this Level (II) which serves as a good indicator of a reduced redox potential (Adams and Weaver, 1958) possibly below a stable thermocline within anoxic sediments. The increase in uranium, TOC, phosphorous and calcium within Level II has been observed by previous workers (Ponsford, 1955; Bloxom and Thomas, 1969 and Spears, 1964). The correlation with phosphorous is probably due to the fixation of uranium in phosphates (Clarke and Young, 1958). The correlation with calcium suggest uranium is present in carbonate-fluorapatite (collophane). A decrease in potassium with an increase in uranium has also been shown by Bloxom and Thomas (1969), they suggest that uranium is not held in illite as Beer and Goodman (1944) seem to indicate (Fig. 5).

Hirst (in Jones, 1965) suggested that sodium/potassium ratios may reflect changes in sedimentation rates. The low ratios in Level II (Fig. 5) may indicate low sedimentation rates which would have allowed larger quantities of degraded illite to lose sodium due to cation exchange near surface waters before becoming deeply buried. These slow sedimentation rates help to explain the very high concentration of goniatites found in this level.

Degens *et al* (1957 and 1958) and Spears and Amins (1981) showed that certain trace elements may be characteristics of specific environments of deposition. Table 1 compares Spears' and Amin's (1981) results with the increase in nickel, zinc, copper, vanadium, chromium and strontium in level II. The trace element concentration in Level II have more "marine-like" values than those in Levels I and III. This indicates deeper waters for Level II than I and III. The coincidence of high TOC in this layer indicates that trace elements may be concentrated in the organic fraction of the shales (Degens *et al* 1957).

Phase 11 has a mixed fauna comprising a condensed regression sequence of phase 1 to 9. *Orbiculoides nitida* is present and seems to have replaced *Lingula* which is less common suggesting that the two were mutually exclusive. However, Calver (1968) in Westphalian marine bands often found them together. Phase 12 (Planolites (A)) indicates a continued regression to shallow brackish water sediments similar to phase 1. The geochemistries of Phases 11 and 12 (Level III) also indicate a shallowing of water depth and a return to redox potential similar to those of Level I.

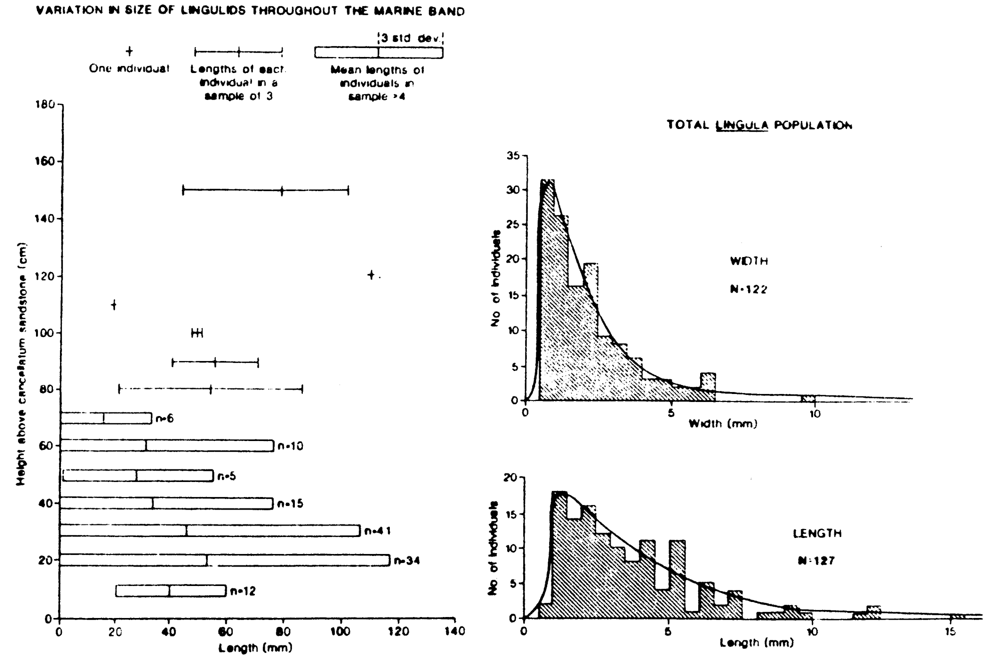

Fig. 4. Variation in size of lingulids throughout the marine band.

Table 1. Comparison of trace elements average and standard deviation from the Glyn Neath Bank and data calculated from eleven samples from different environments taken from Degens *et al.* (1957).

	Degens *et al* (1957)						This study	
	Fresh water		Brackish water		Marine		Glyn Neath Bank	
	Mean (ppm)	Std Dev.	Mean (ppm)	Std Dev.	Mean (ppm)	Std Dev.	Mean (ppm)	Std Dev.
Ba	577	254	545	82	455	121	535	48
Cr	110	47	67	11	62	20	103	18
Cu	77	22	74	21	74	19	23	20
Ni	26	7	22	11	50	25	62	12
Sr	363	128	500	148	445	93	122	14
V	50	16	35	13	45	14	128	22
Z	-	-	1500	-	550	31	81	19

Conclusions

The G. cancellatum Marine Band is more complex than Jones' (1965) three-fold division for G1 marine bands. The fauna contrasts markedly with the G. cancellatum Marine Band in Northern England which had a less varied fauna comprising *Caneyella, Dunbarella, Cancelloceras* and *Reticuloceras* (Heptonstall, 1964) and shows a greater similarity to Belgium faunas (Swan, pers. comm.). This is because during Carboniferous times Southern Britain, Belgium and France were small interconnecting basins and were a distinct faunal province, whilst the Central Pennine Basin was separated from this province by the Wales Brabant massif.

The faunal phases compared favourably with Calver's (1968) Westphalian marine bands, which indicated progressively deeper water facies with a marine incursion and a return to shallow water facies with a marine regression. However, the G. cancellatum Marine Band in South Wales is asymmetric, Phases 1 to 9 represent progressively deeper water faunas and a sudden deepening from Phase 9 to Phase 10 with a condensed Phase 11 containing fauna present in Phase 1 to 9 returning to shallow water fauna of Phase 12 (Fig. 6).

The three-fold geochemical division indicates a large change of water depth probably in the order of tens of metres in Level II corresponding to Phase 10. This represents a change from an environment (Level I) in which sediments have low TOC and low uranium levels to an environment in which sediments were anoxic with reduced redox potentials and therefore higher TOC and uranium levels. This was also reflected in the increase of the trace elements nickel, zinc, copper, vanadium, chromium and strontium and a decrease in barium in Level II. Level III (Phases 11 and 12) had sediments with geochemistries similar to Level I indicating a return to geochemical environments of shallower waters.

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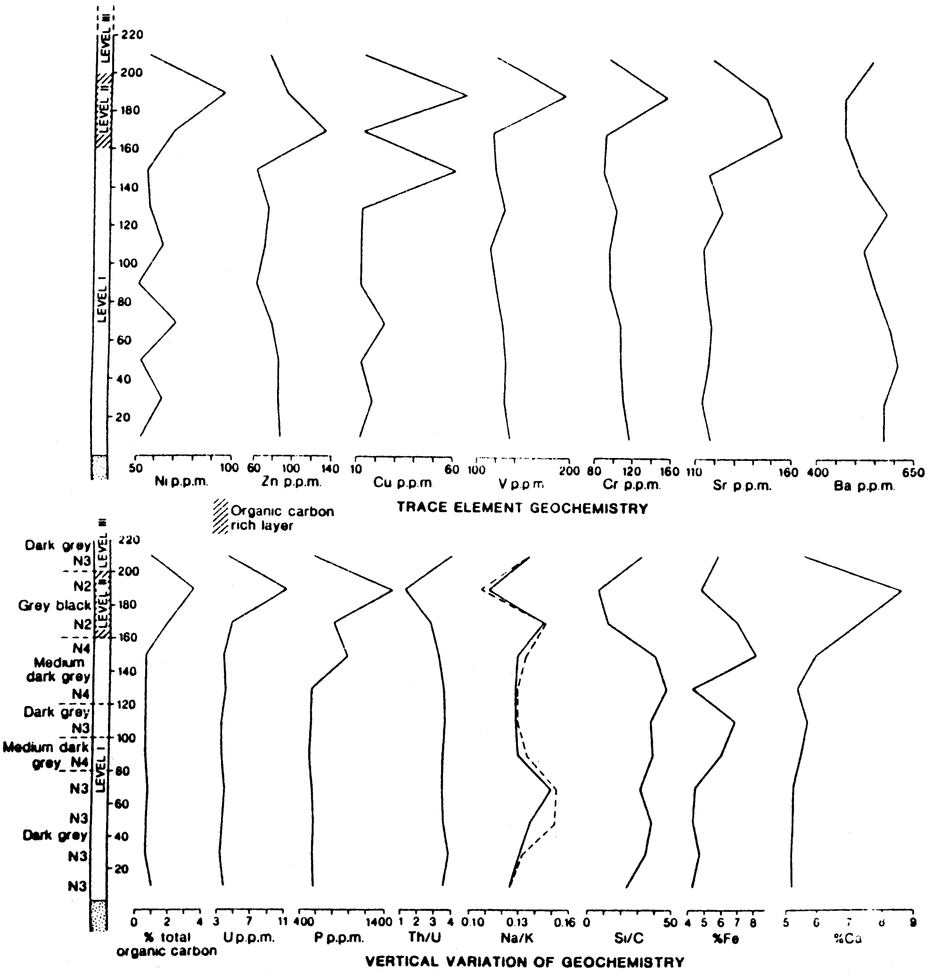

Fig. 5. Vertical variation of geochemistry throughout the marine band.

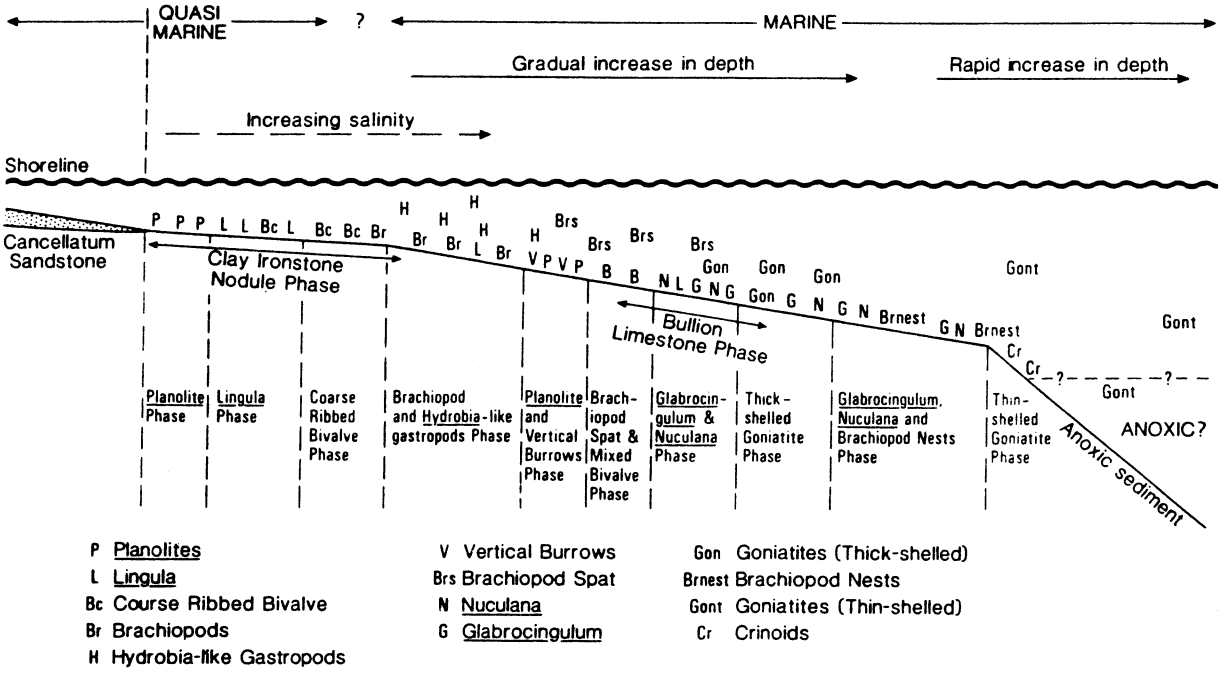

Fig. 6. Model for the environment and faunal phase of the Gastrioceras cancellatum Marine Band.

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