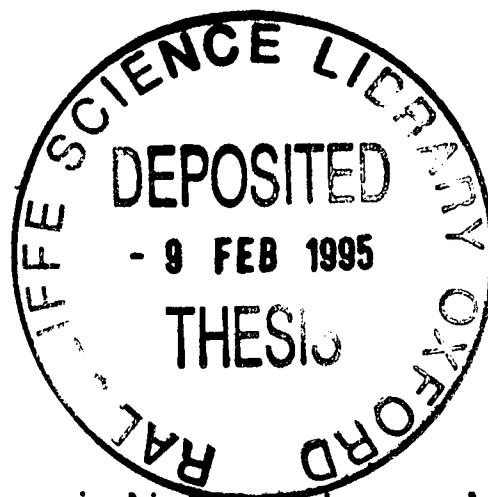


A Thesis Presented for the Degree of Doctor of Philosophy

The Sequence Stratigraphy of the Lower Jurassic of Western Europe

Volume 2: Figures



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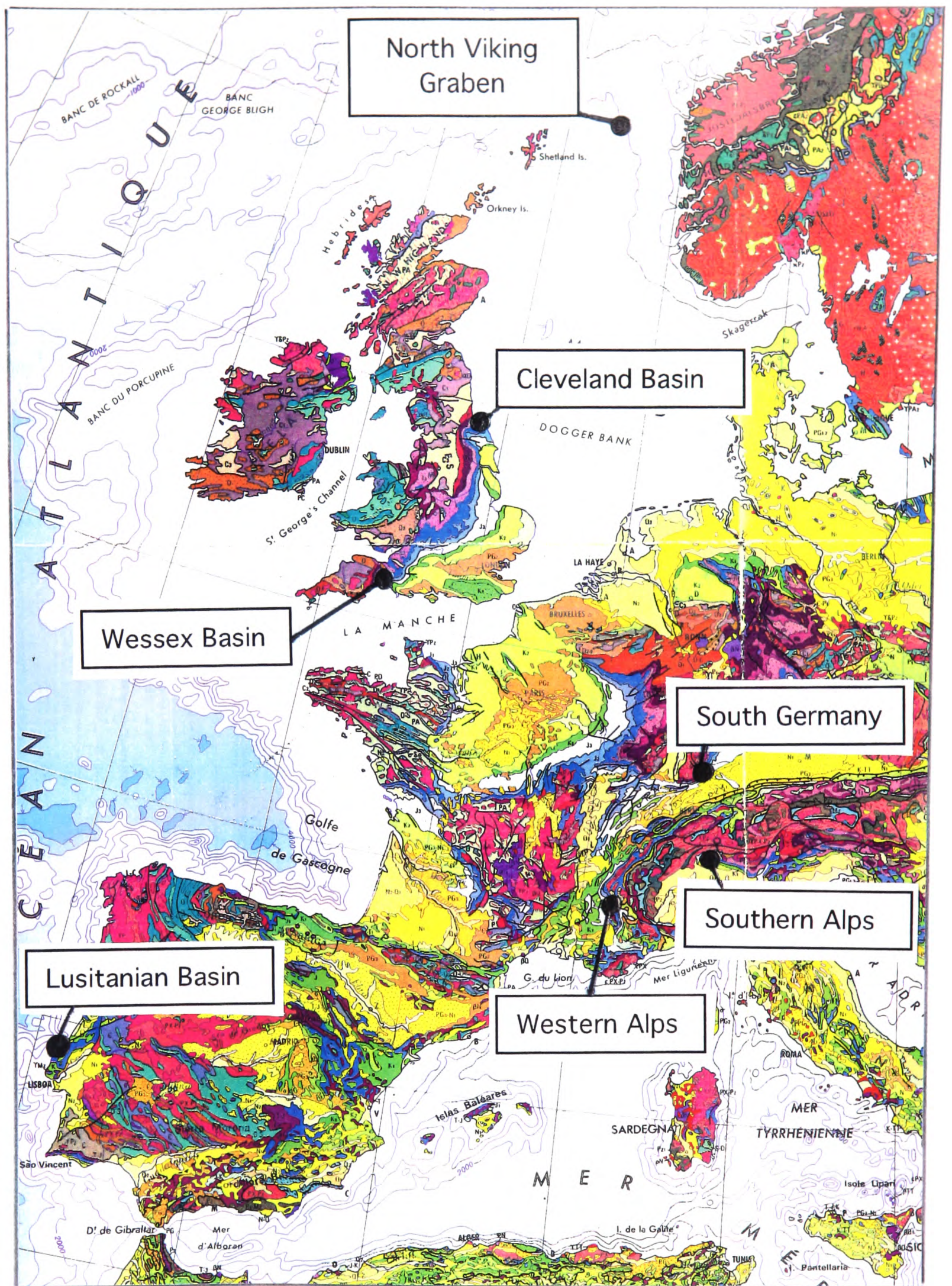


Figure 1.1 Geological map of Western Europe (Early Jurassic in dark blue), showing locations of study areas.

Map reproduced from Sheet 9 of the UNESCO Geological World Atlas

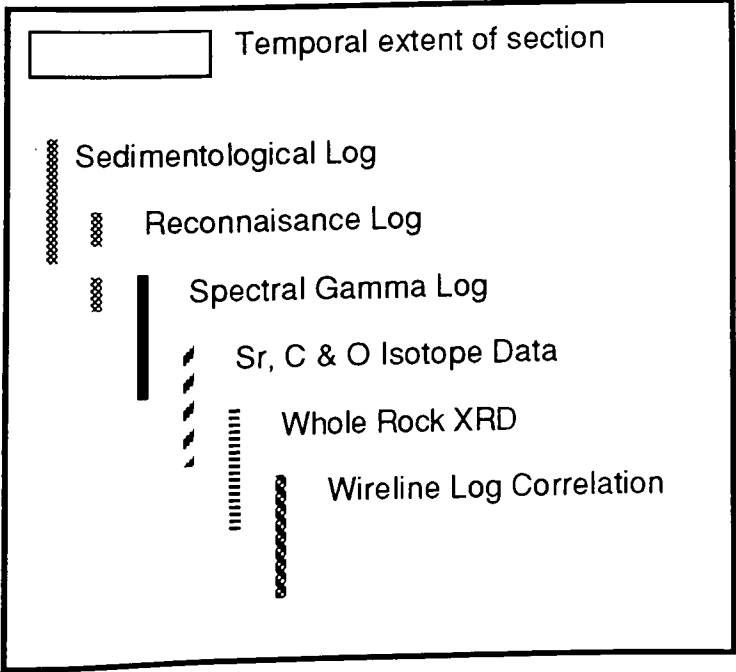
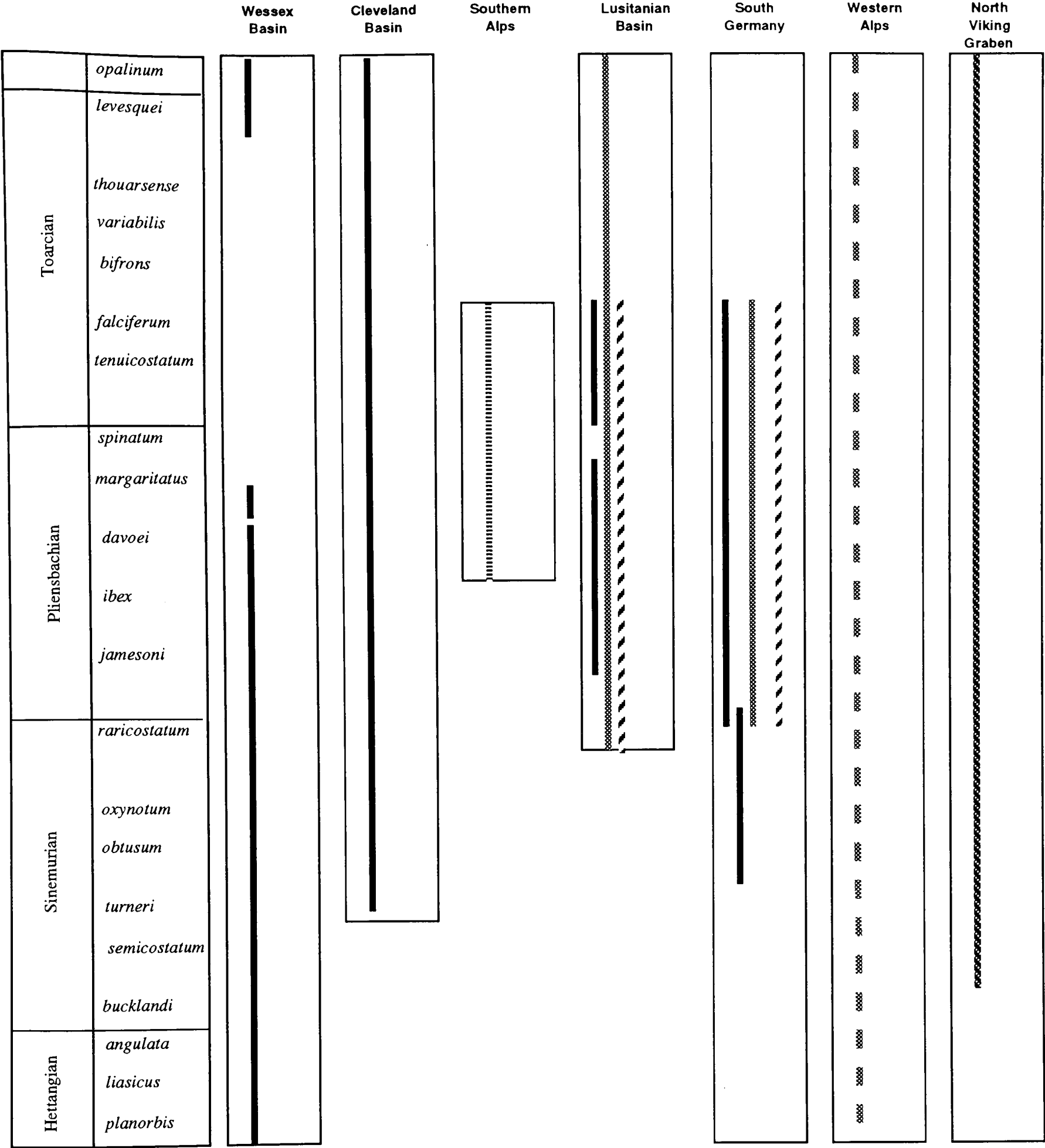


Figure 1.2 Summary of new data acquired for this thesis

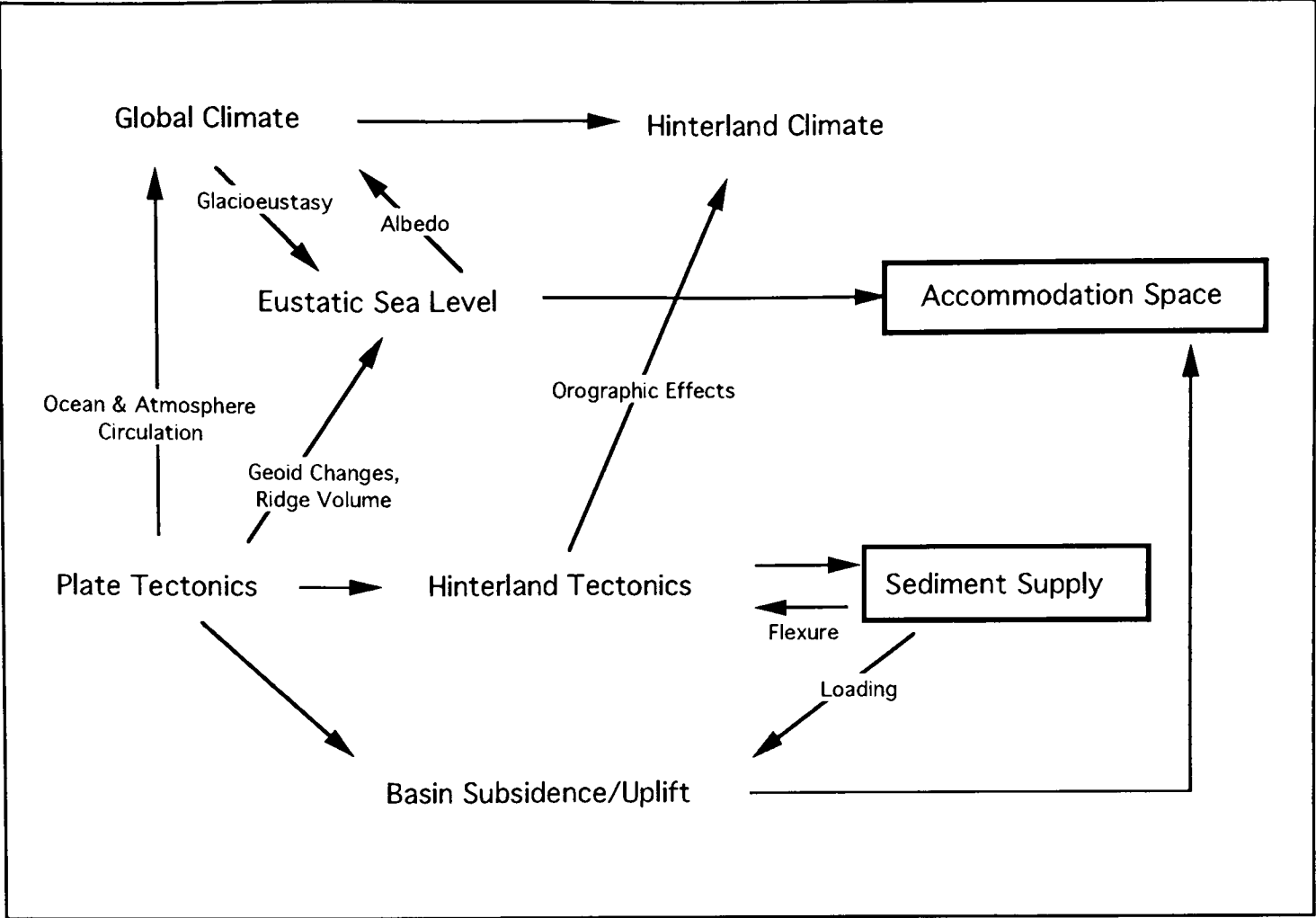


Figure 2.1a Some controls on the development of the stratigraphic record, illustrating the interdependence of variables and the importance of feedbacks.

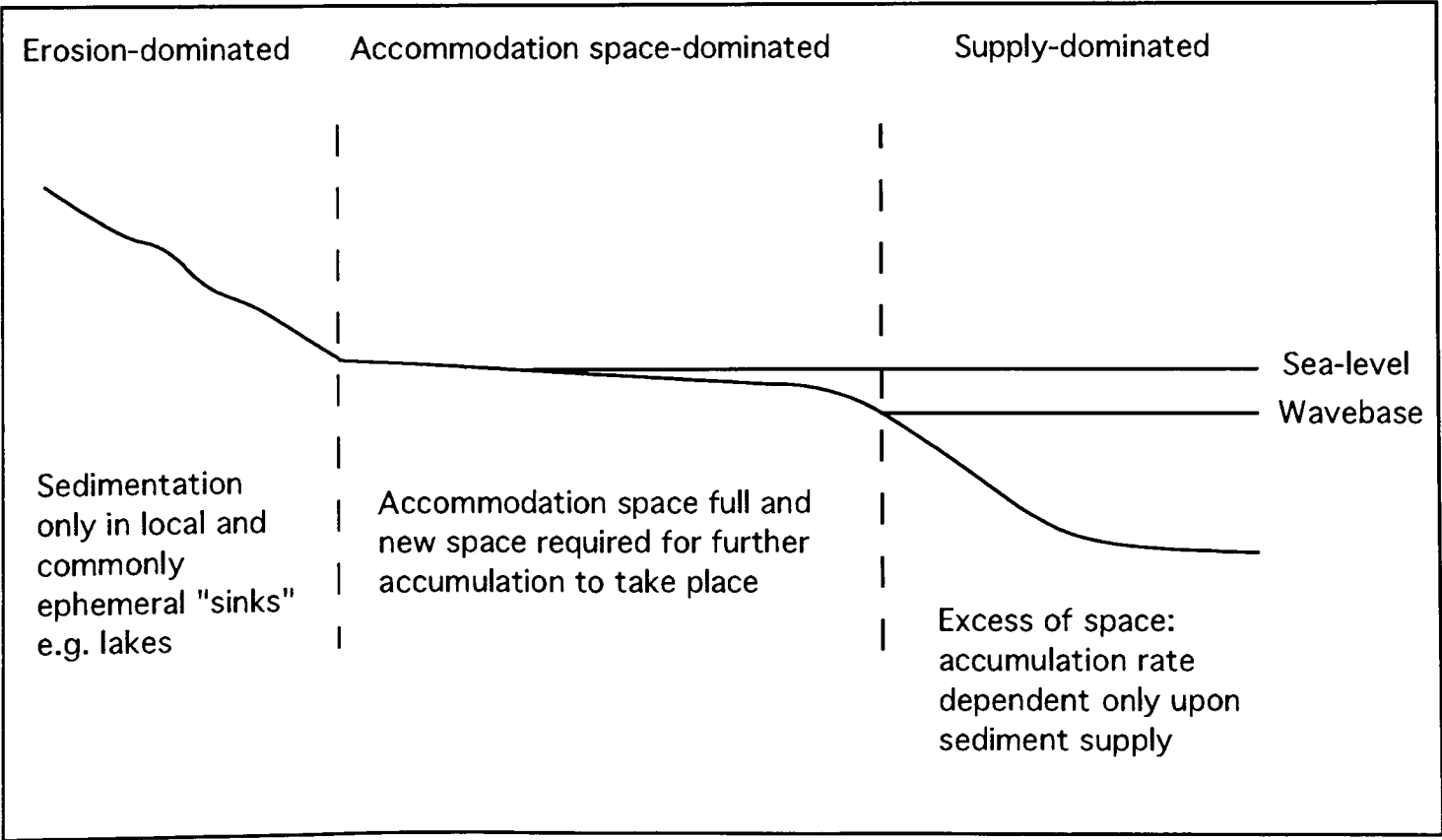


Figure 2.1b Erosion, accommodation space and supply-dominated settings

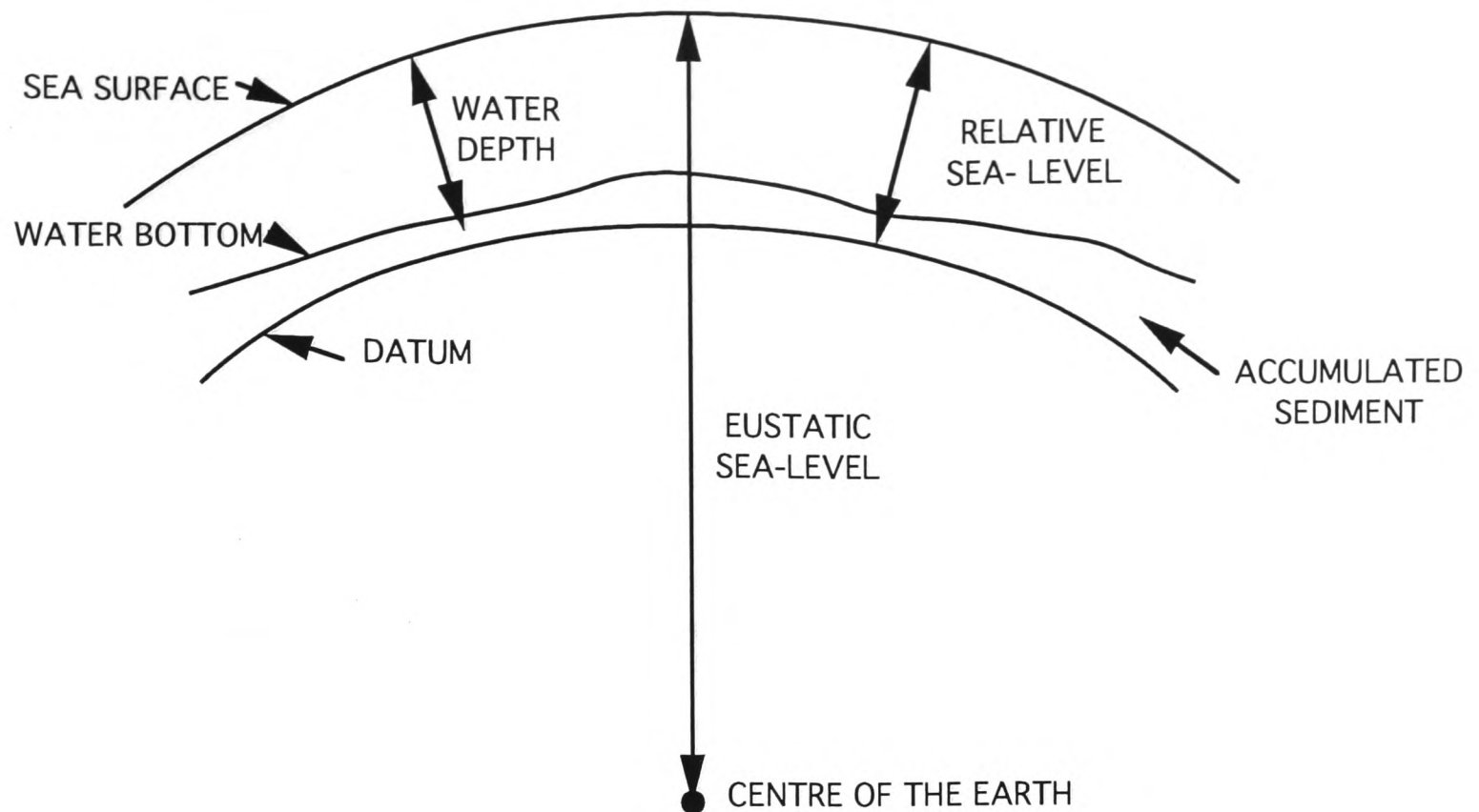


Figure 2.2a Definitions of eustatic and relative sea-level, and water depth (after Posamentier, Jervey & Vail, 1988)

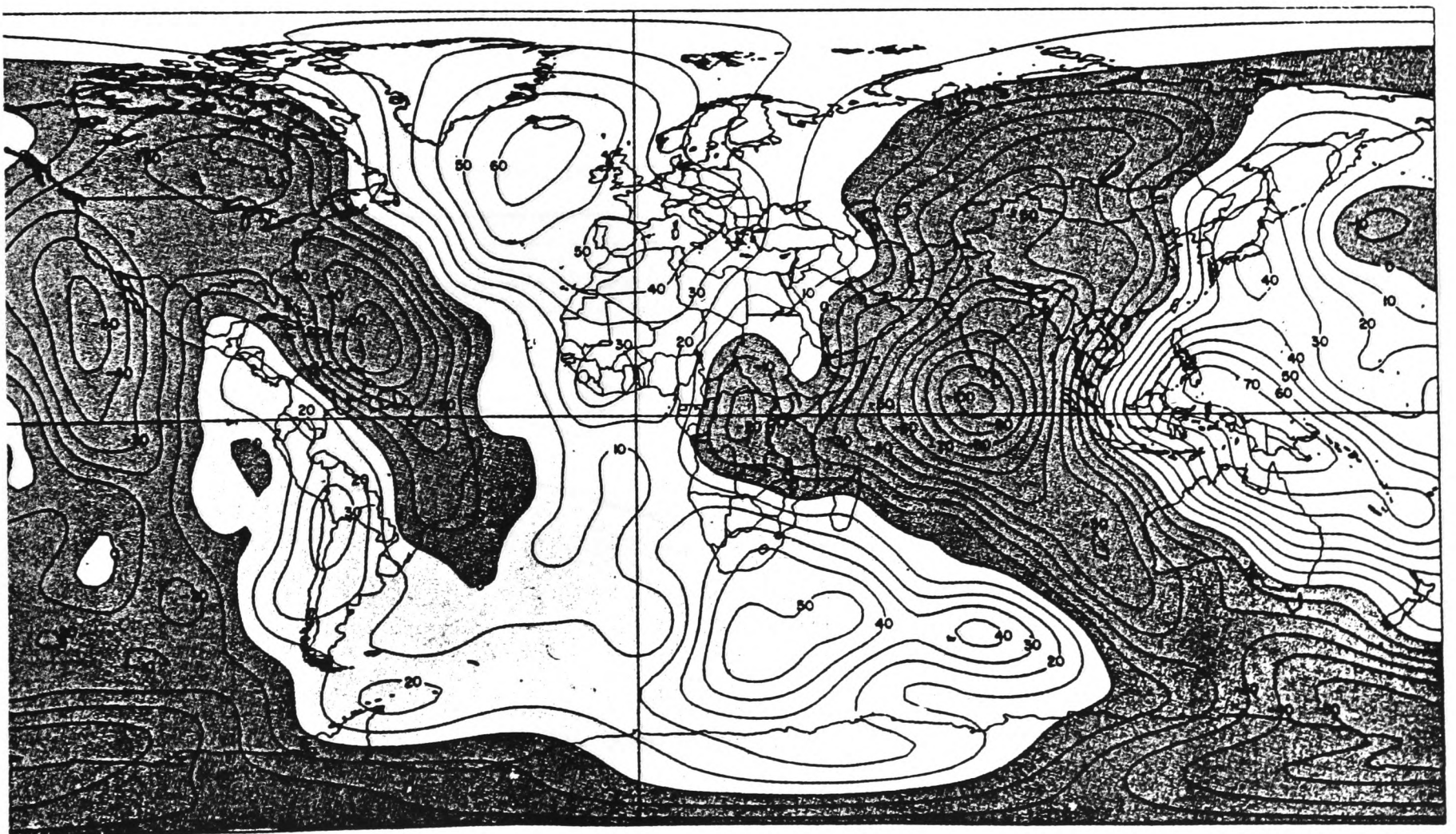


Figure 2.2b The present-day geoid, equivalent to the shape of the eustatic sea level surface. There is 170m of topography on this surface, which is presumed to reflect the internal structure of the earth and is likely to have varied over geological time (contours in metres with respect to the best-fitting ellipsoid, $f = 1/298.256$, from Morner, 1976).

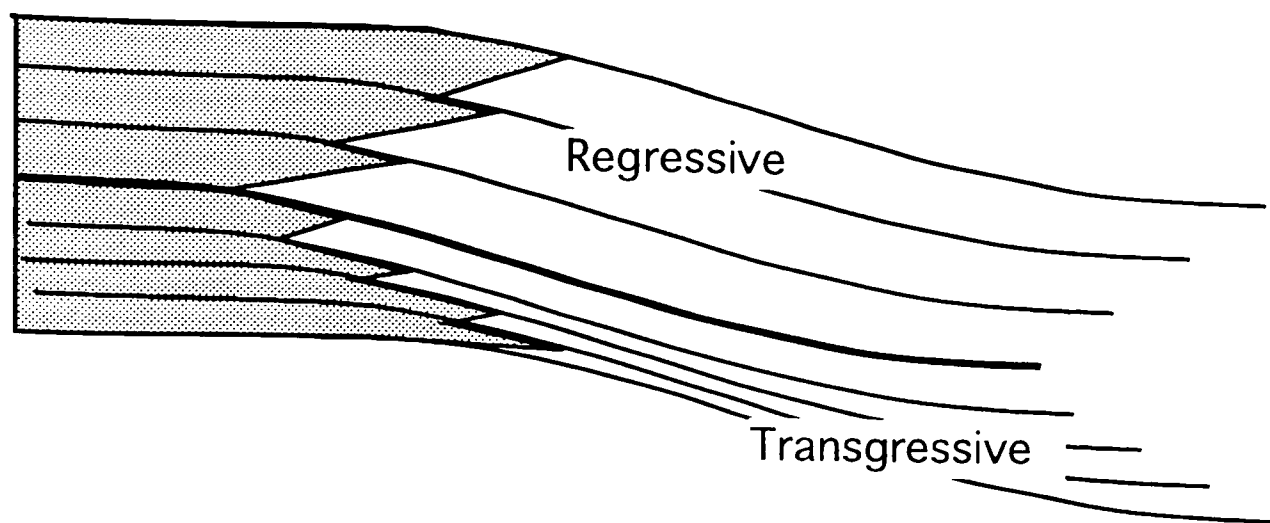


Figure 2.3a Two-fold division of stratigraphy into transgressive and regressive intervals.

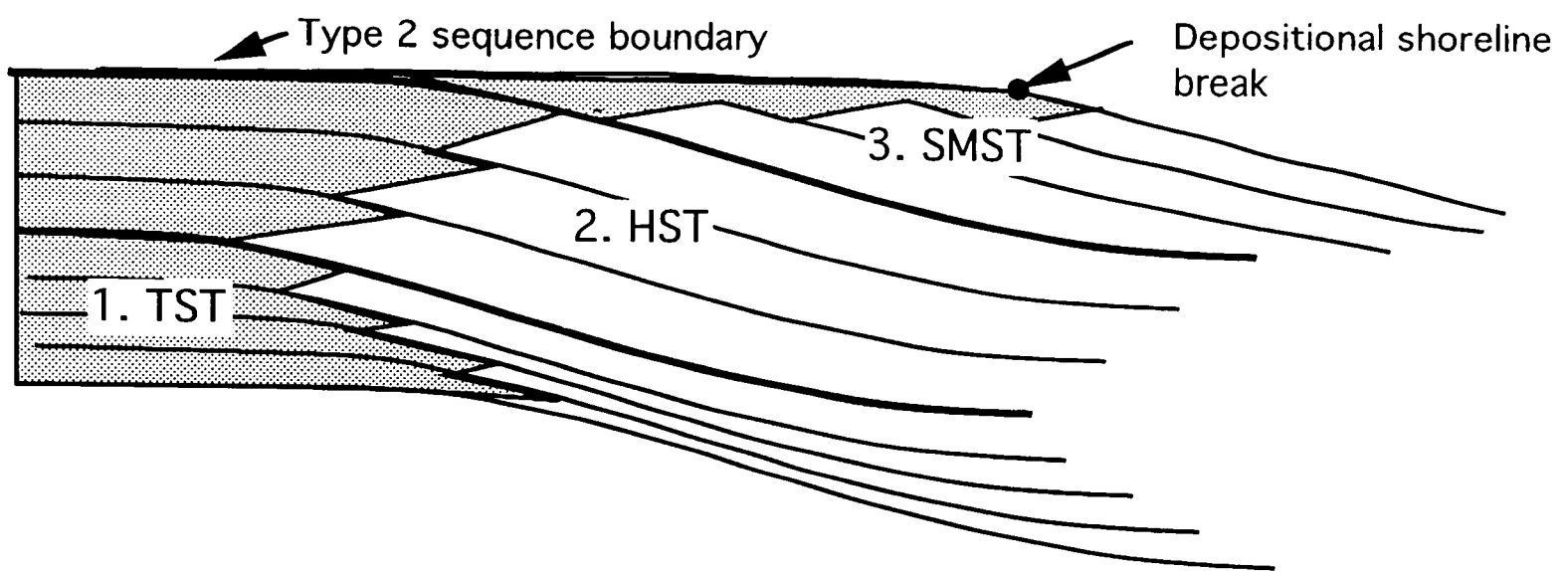


Figure 2.3b Three-fold division of stratigraphy produced by allowing relative sea-level to fall (numbers refer to text)

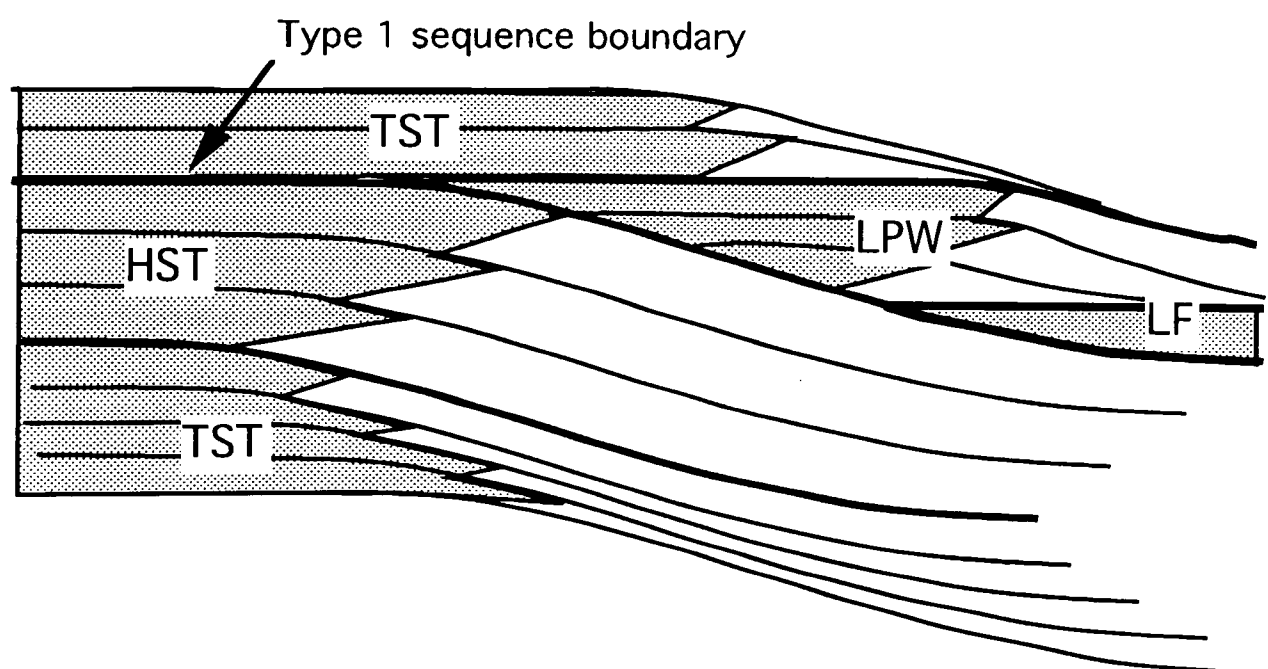
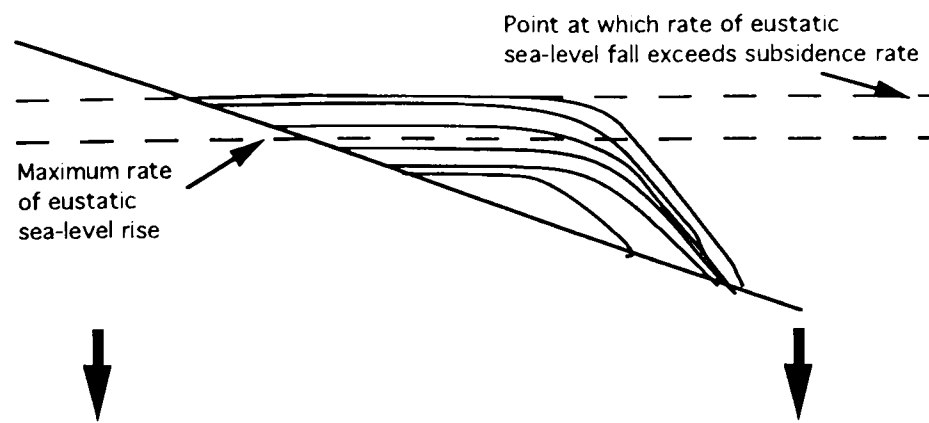
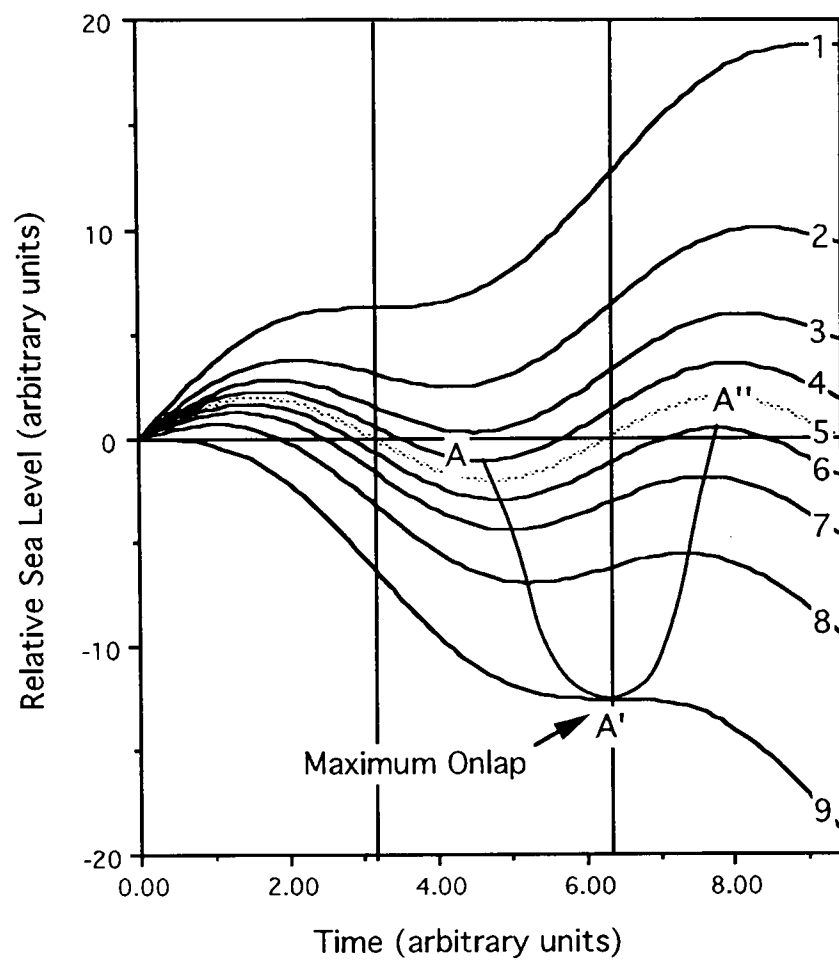


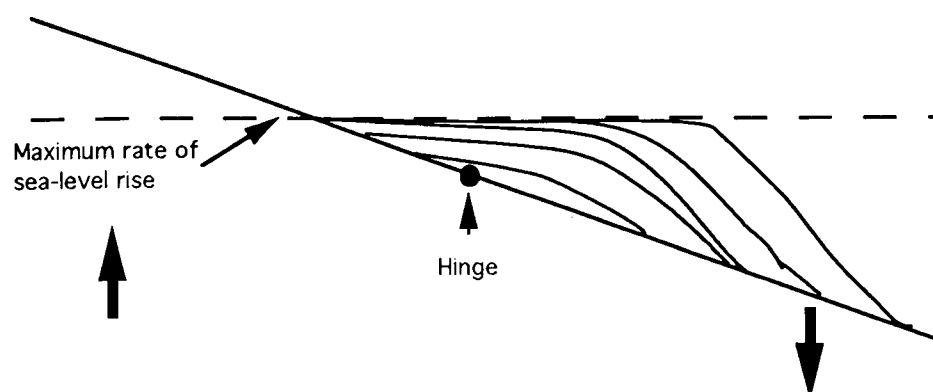
Figure 2.3c Variant upon 2.3b, where relative sea-level falls below the level of the underlying depositional shoreline break



a) Spatially uniform subsidence: maximum onlap occurs immediately before the rate of eustatic sea-level fall exceeds the subsidence rate.



b) Relative sea-level curves for a various linear subsidence rates combined with a sinusoidally-varying eustatic curve. Curve 1, most rapid subsidence; curve 5, hinge; curve 9, most rapid uplift (see text for discussion).



c) Stratal patterns produced by a tectonic hinge. Maximum onlap coincides with the maximum rate of eustatic sea-level rise.

Figure 2.4 The effects of a hinge line on the timing of maximum onlap

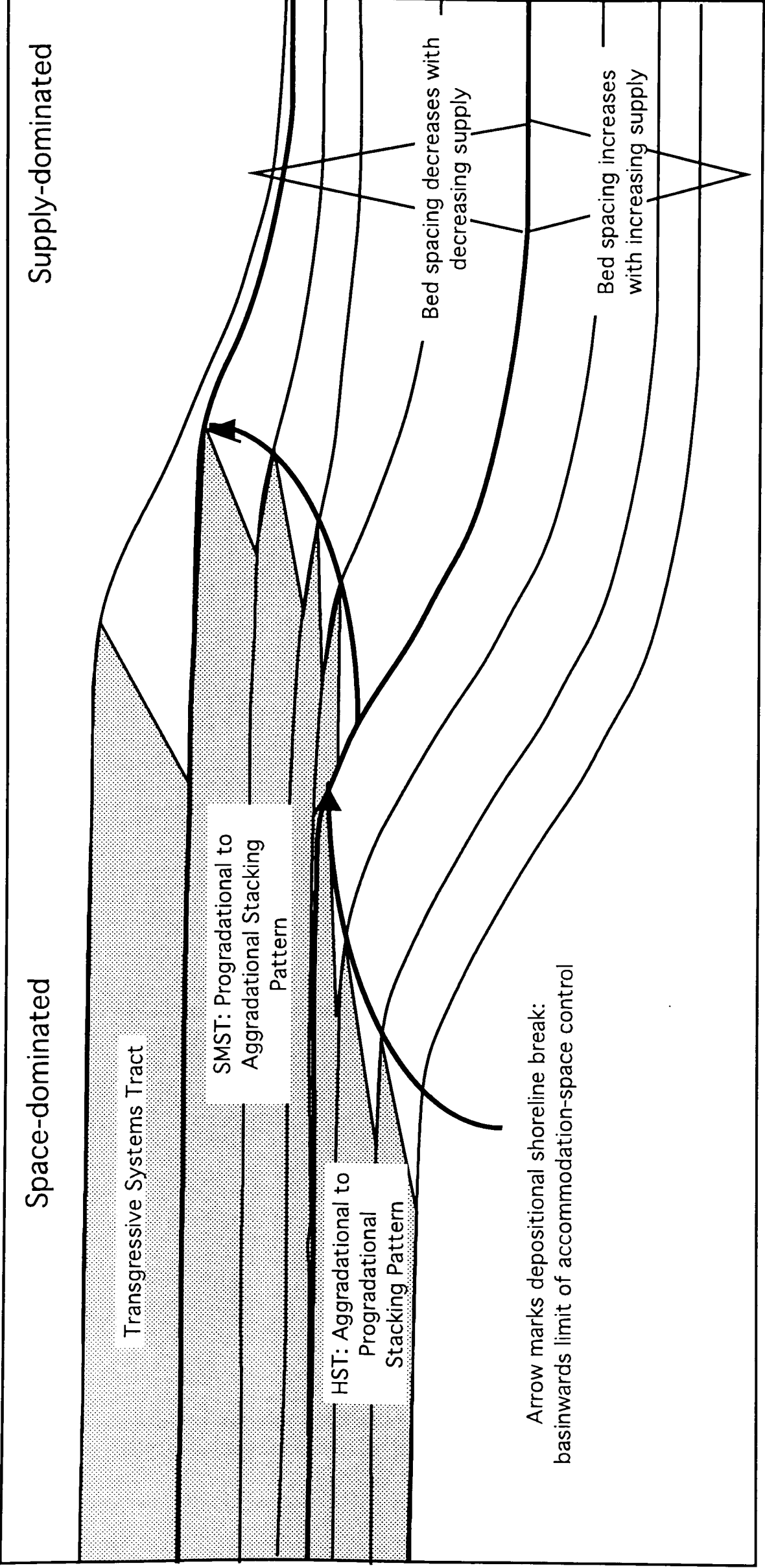
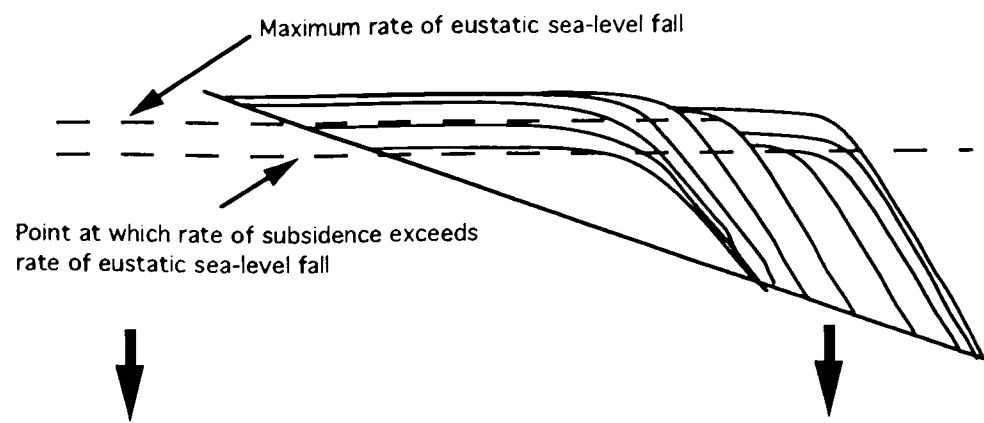
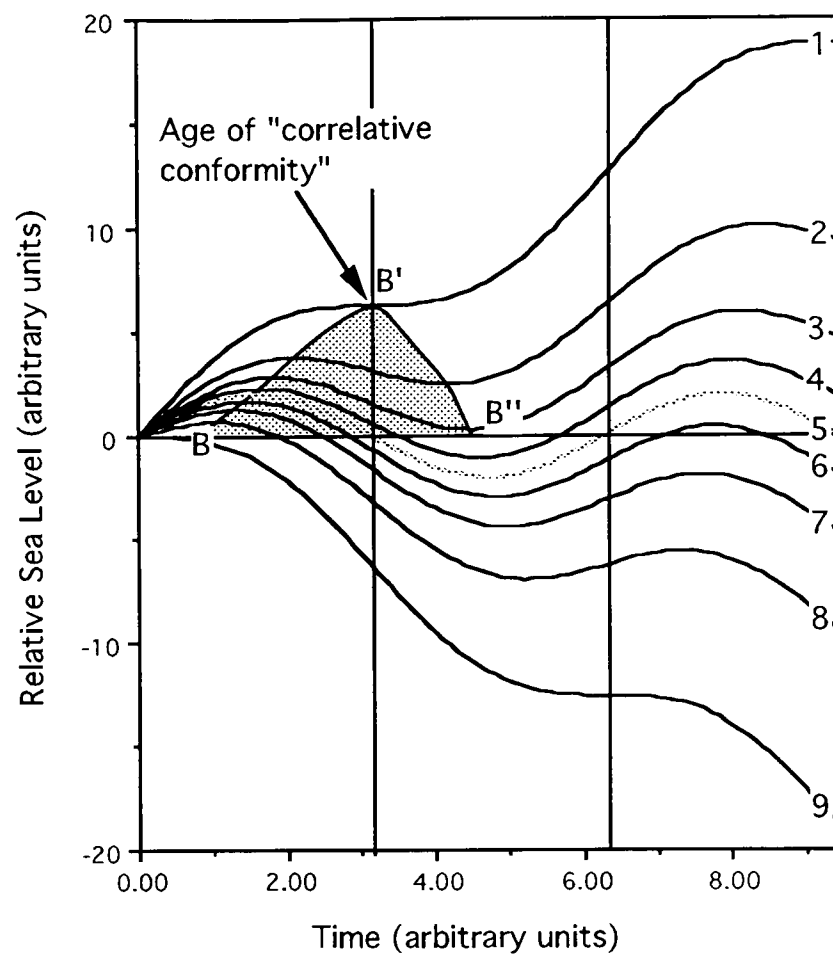


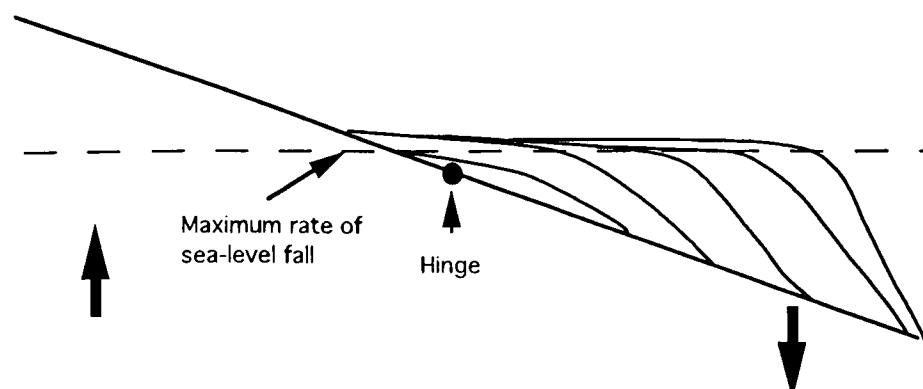
Figure 2.5 Stacking patterns associated with Highstand and Shelf Margin Systems Tracts in proximal and distal settings.



a) Spatially uniform subsidence: correlative conformity occurs when rate of tectonic subsidence exceeds rate of eustatic sea-level fall.



b) Relative sea-level curves for a various linear subsidence rates combined with a sinusoidally-varying eustatic curve. Curve 1, most rapid subsidence; curve 5, hinge; curve 9, most rapid uplift (see text for discussion).



c) Stratal patterns produced by a tectonic hinge. Correlative conformity coincides with the maximum rate of eustatic sea-level fall.

Figure 2.6 The effects of a hinge line on the timing of the "correlative conformity" (sequence boundary)

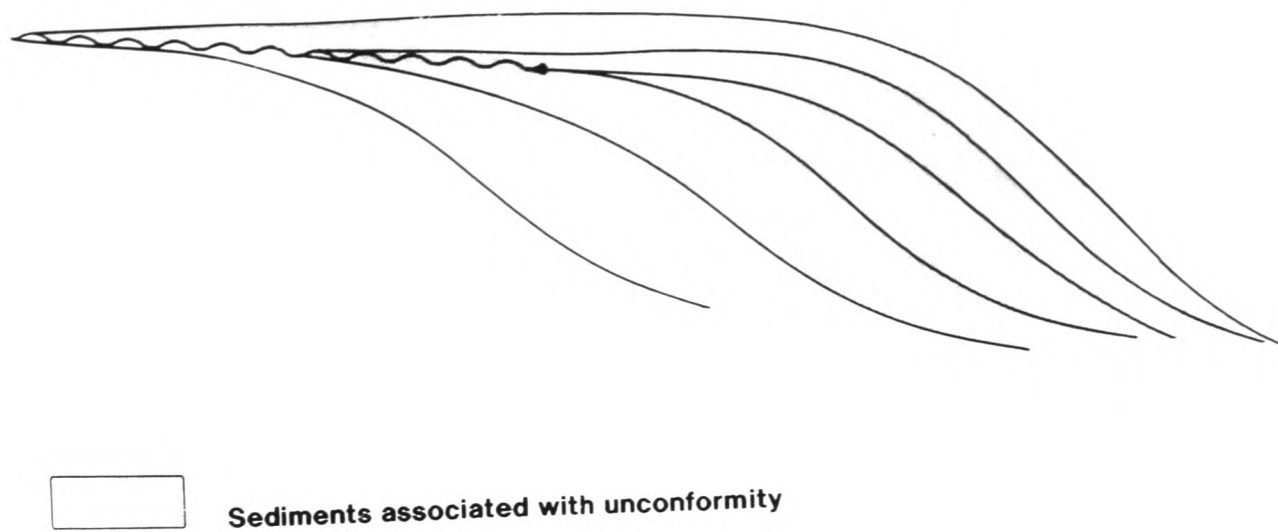


Figure 2.7a Erosion products from a relative sea-level fall may be seen in a basin before the most rapid rate of relative sea-level fall is attained.

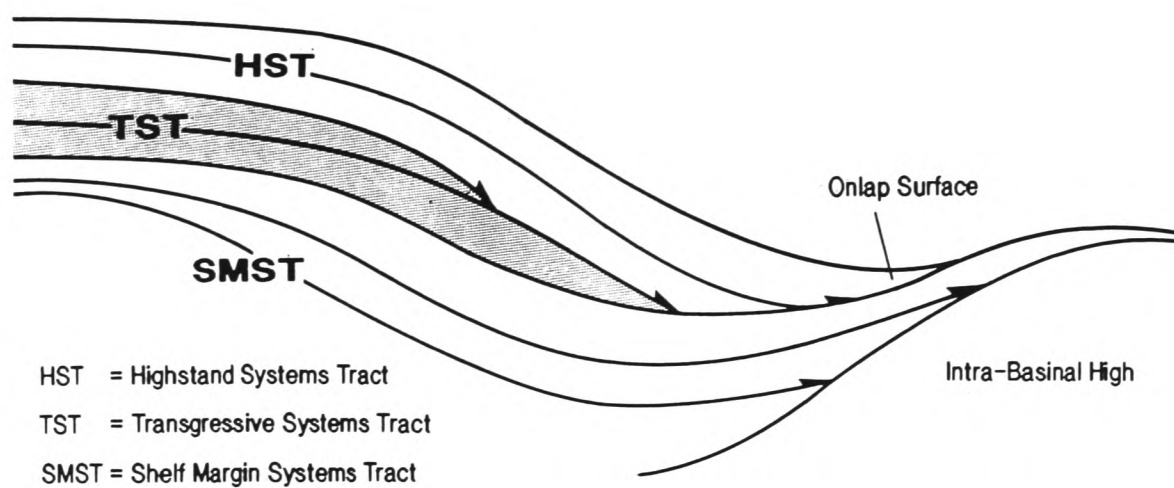


Figure 2.7b Model for the starvation of intra-basinal highs during periods of low sediment supply to the basin.

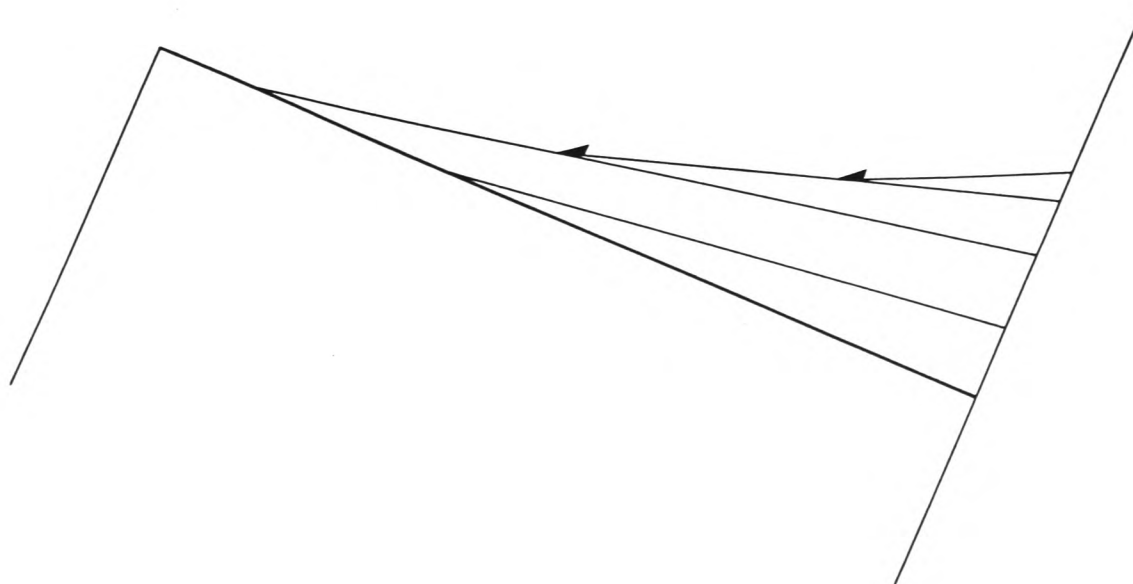


Figure 2.7c Onlap within a starved half-graben is a function both of sediment supply and tilt-rate.

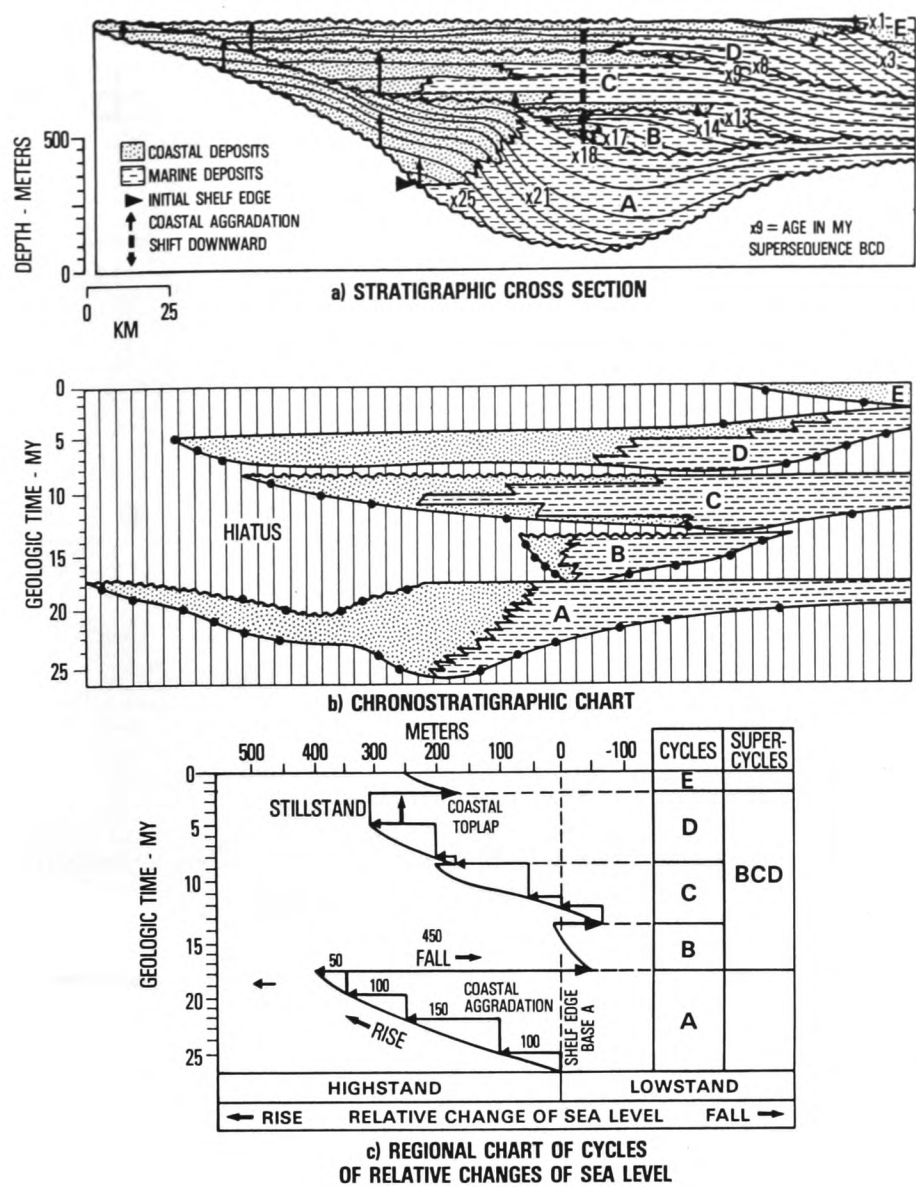


Figure 2.8a Method of constructing a chart of relative changes of sea level from seismic data (from Vail et al., 1977a)

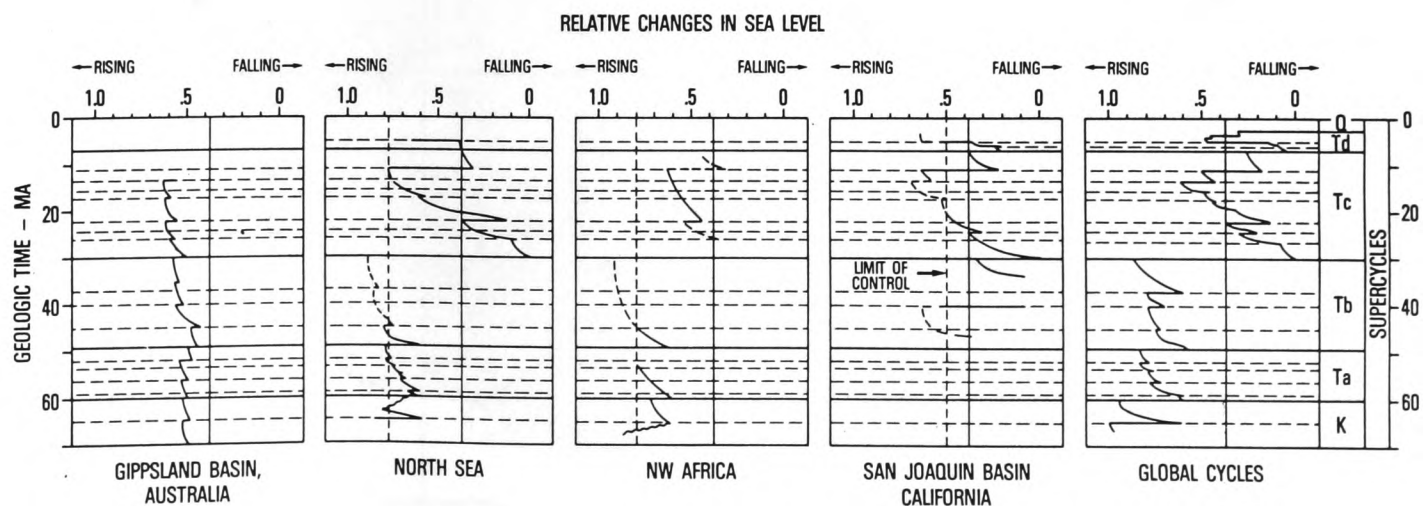
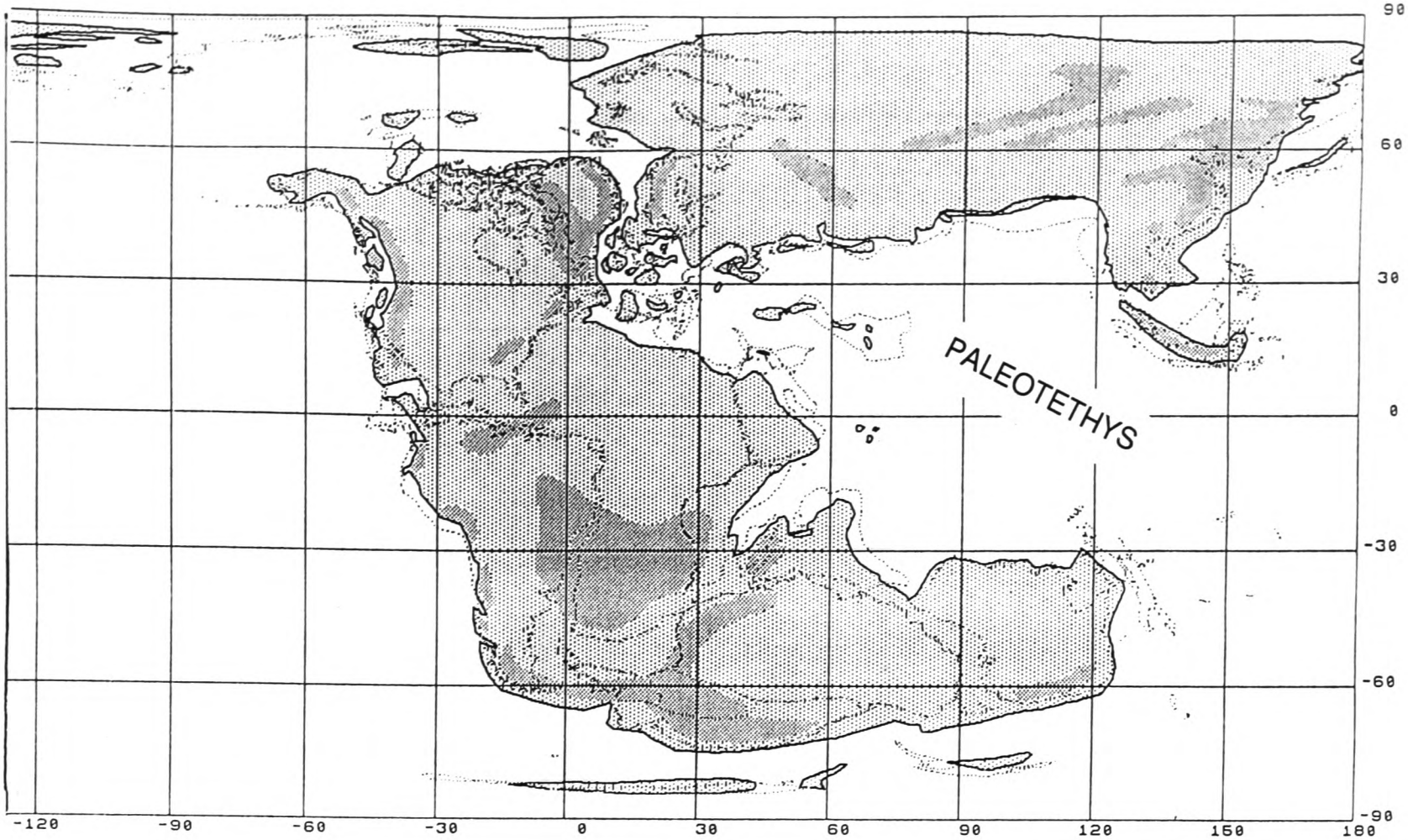


Figure 2.8b Method of "averaging" regional cycles, constructed by the method shown in figure 2.7a, to produce a "global cycle chart" (from Vail et al., 1977b). Note that many of the features of the global chart appear on only one or two of the regional charts.

Hettangian coastlines



Toarcian coastlines

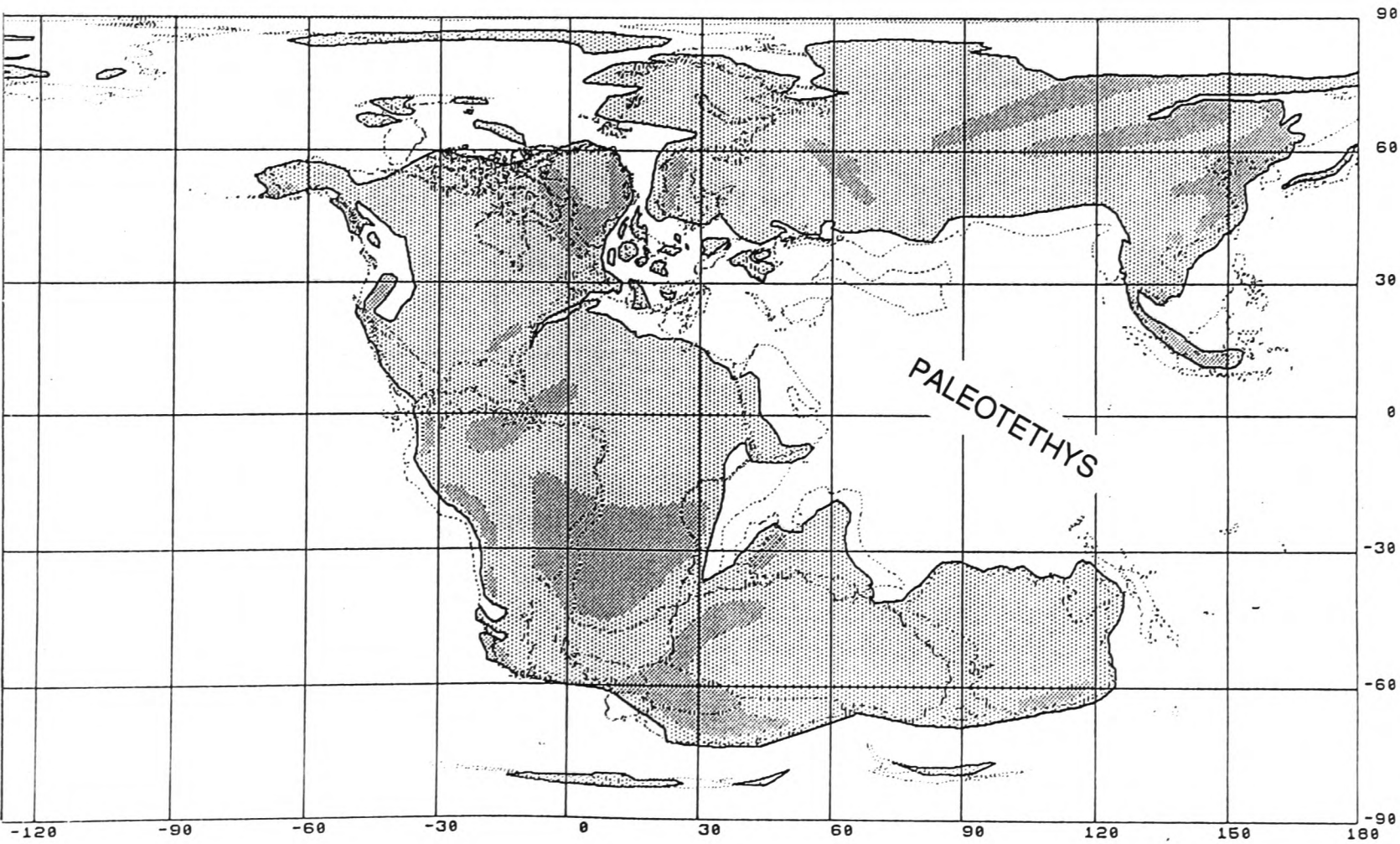


Figure 3.1 Plate reconstructions and paleoshorelines for the Hettangian & Toarcian (unpublished data courtesy of Dr. A. G. Smith, University of Cambridge)

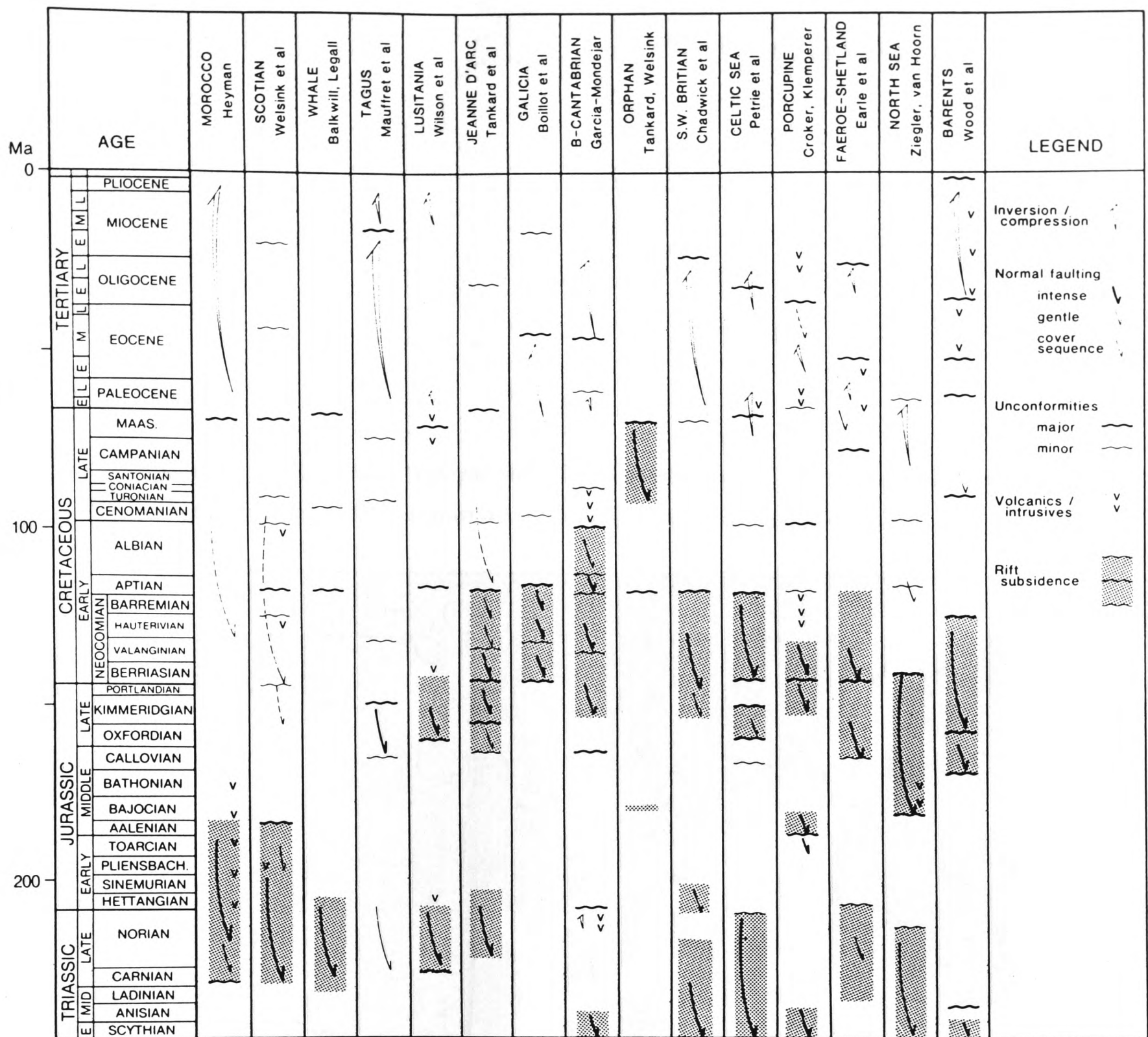


Figure 3.2 Summary of rifting episodes in the North Atlantic area (from Tankard & Balkwill, 1989: references refer to the Tankard & Balkwill volume)

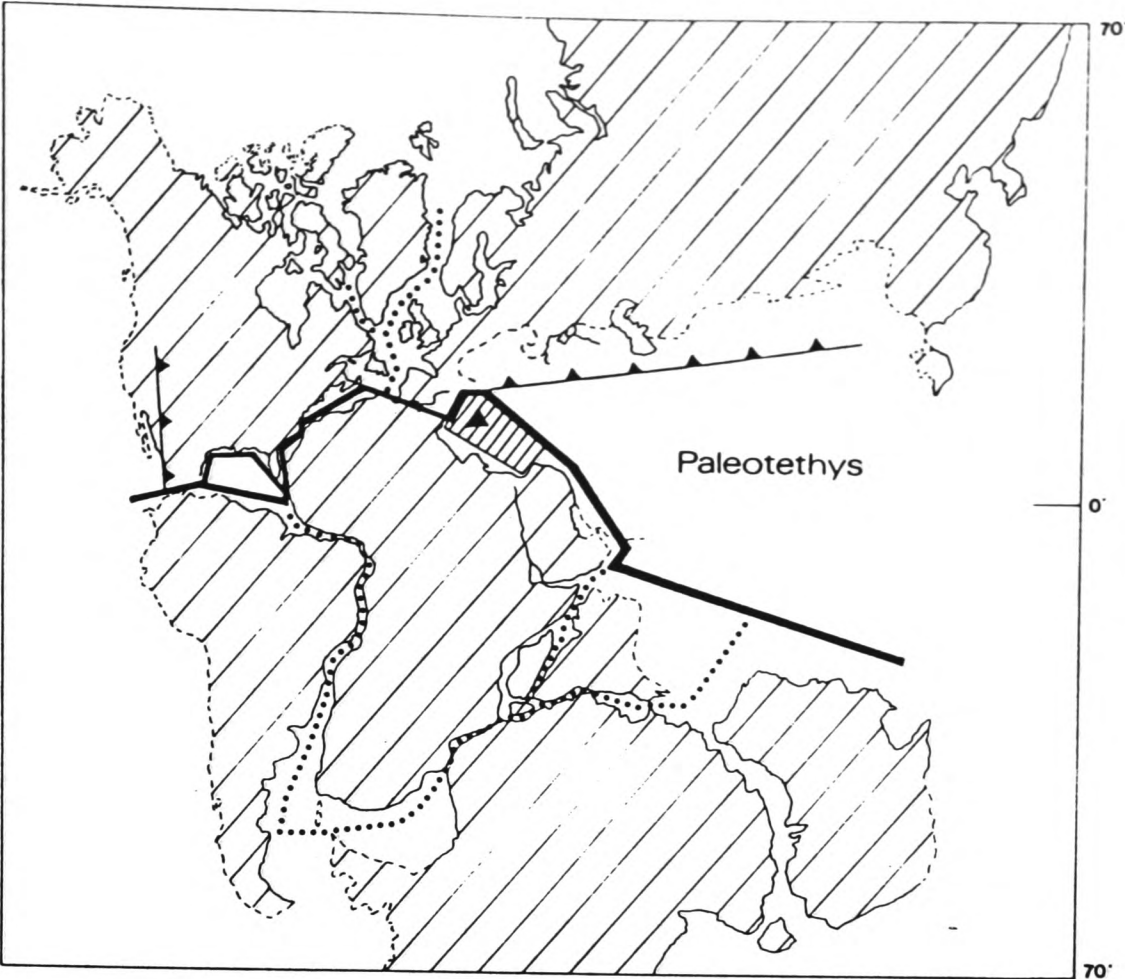


Figure 3.3 The line of the "Tethyan Rift", shown in heavy black, with subsequent Cretaceous-Tertiary spreading centres shown dotted (from Laubscher & Bernoulli, 1977)

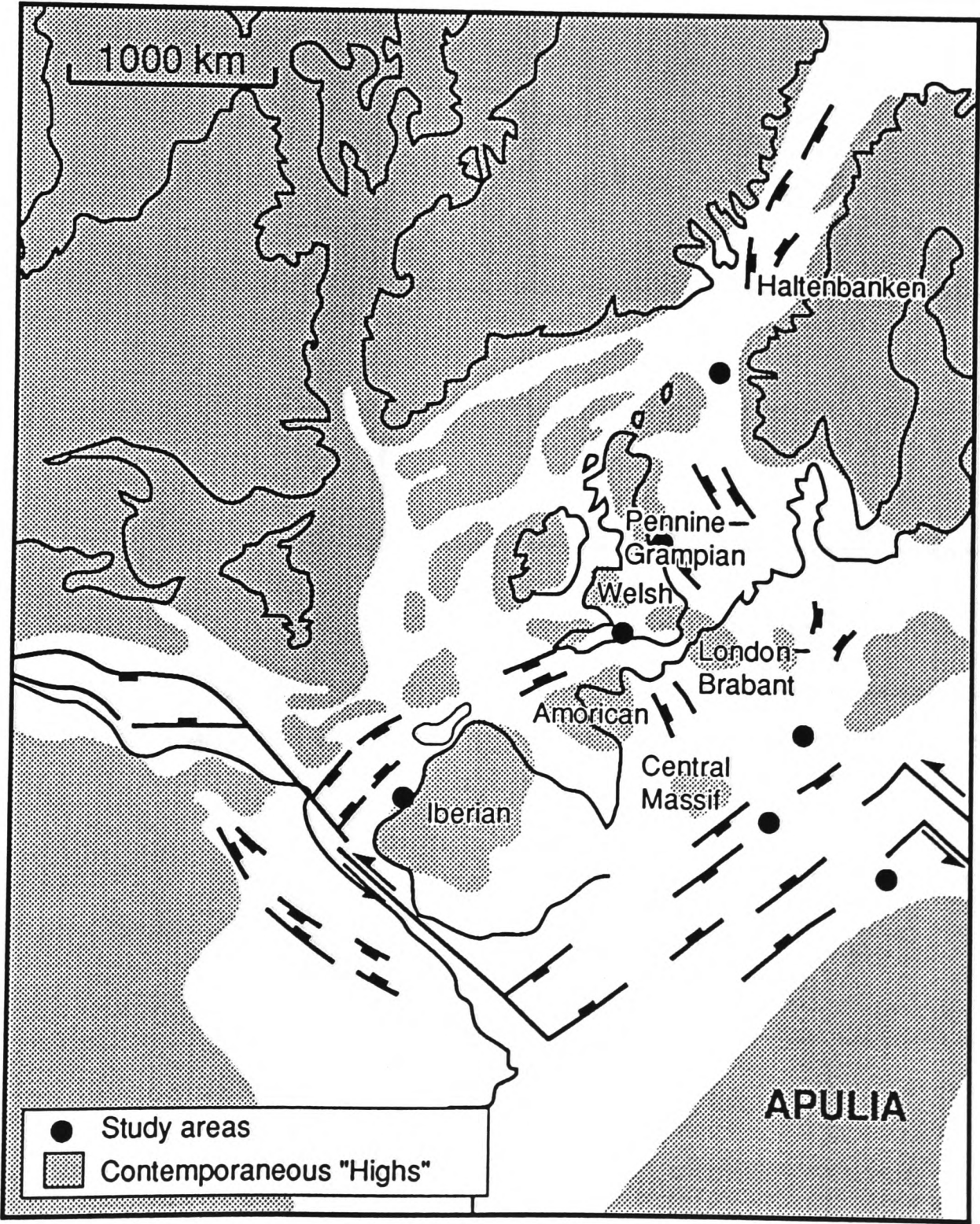


Figure 3.4 Generalised Lower Jurassic Paleogeography of Western Europe (after Ziegler, 1988 and Lemoine, 1983)

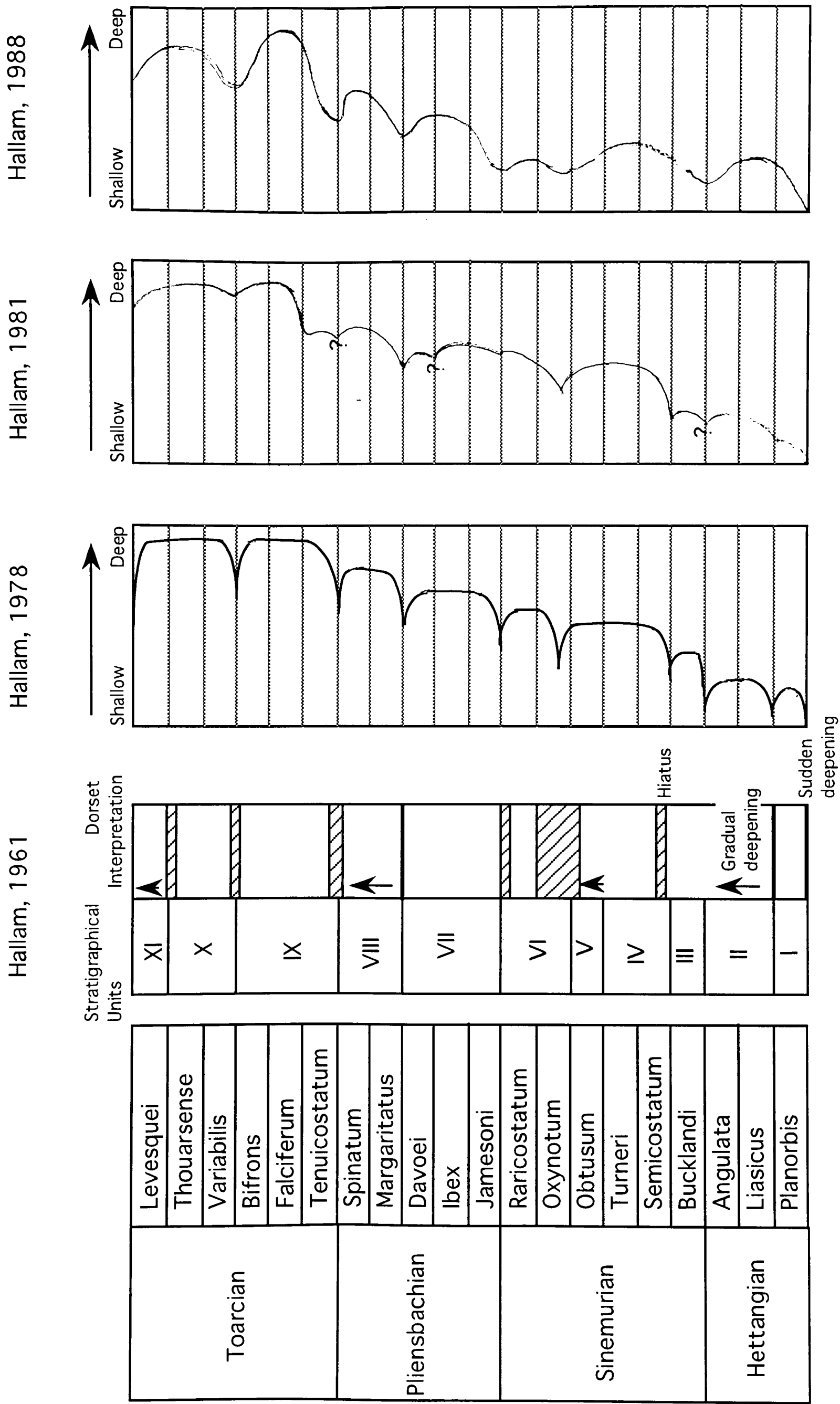


Figure 3.5 Hallam's Sea-Level Curves for the Lower Jurassic: 1961-1988

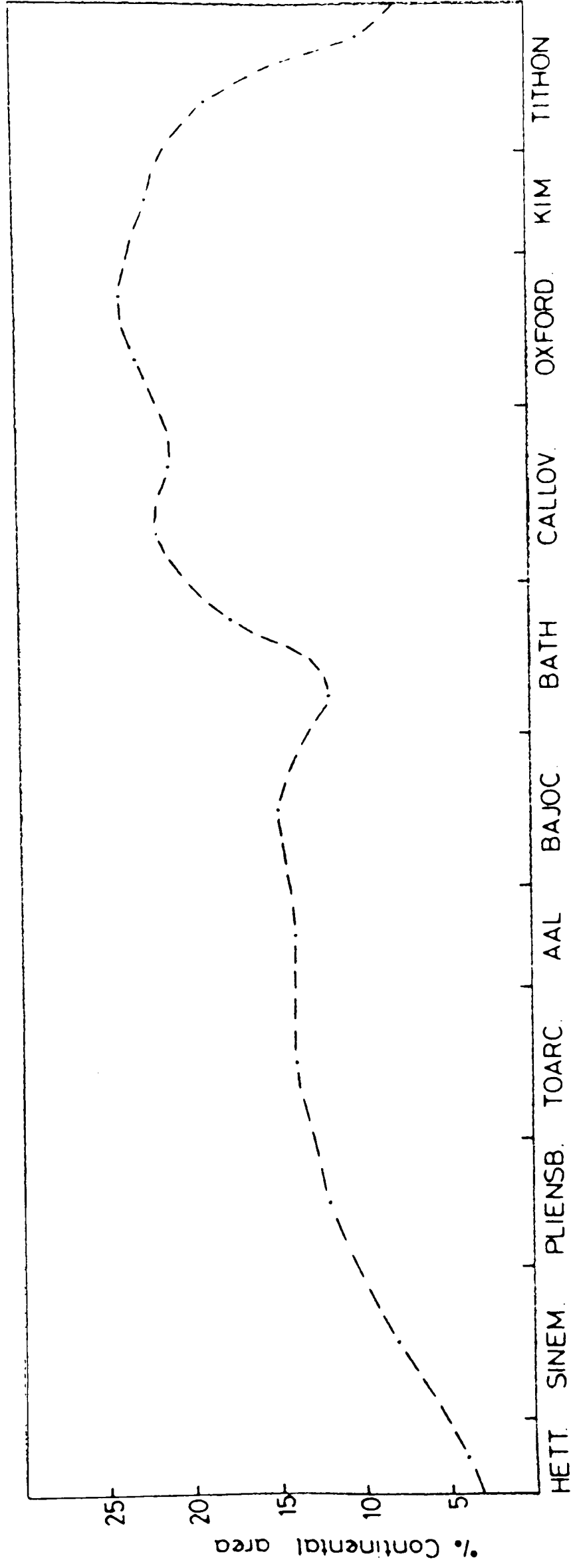


Figure 3.6 Marine inundation during the Jurassic based on the planimetry of global paleogeographic maps (from Hallam, 1969)

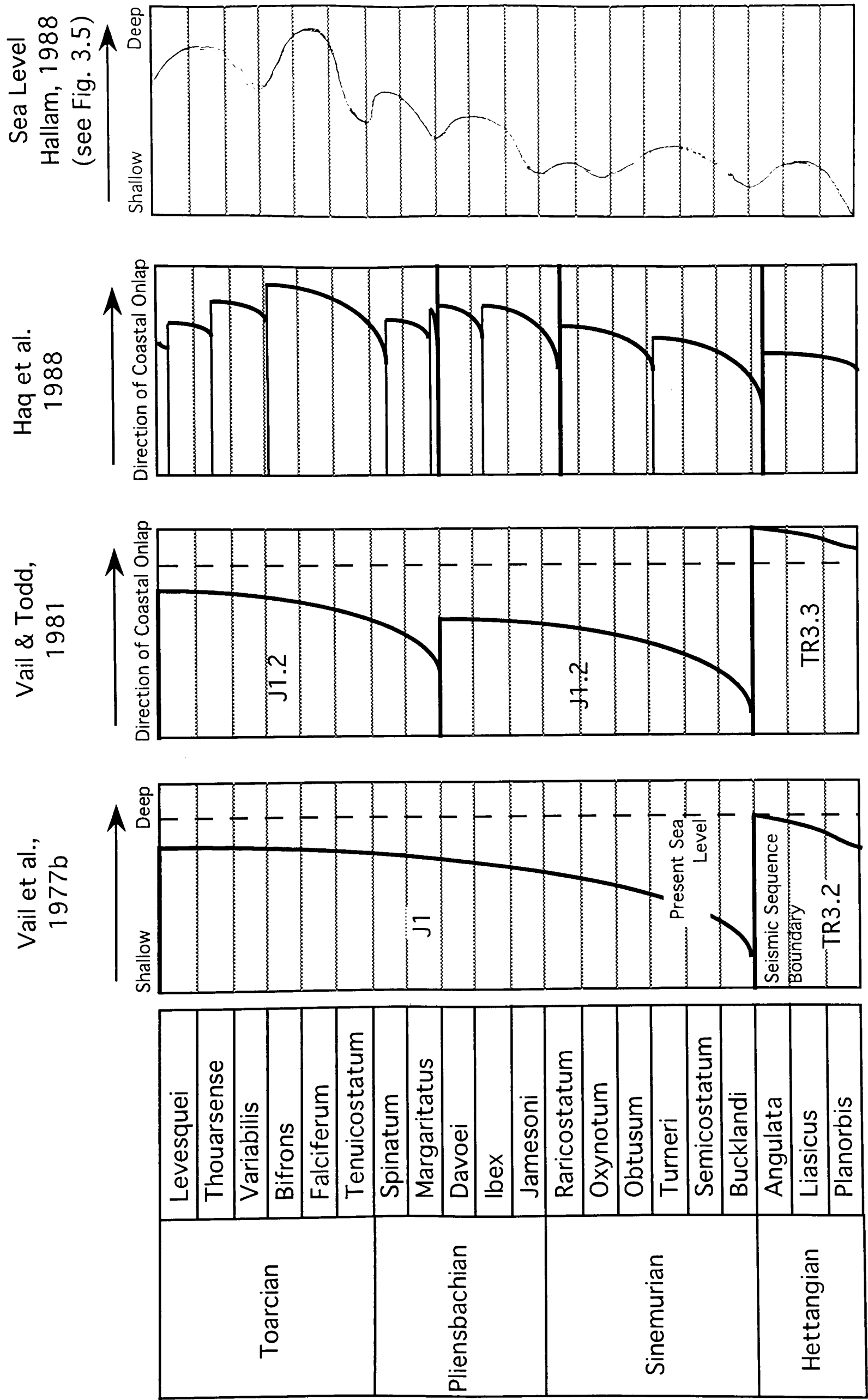


Figure 3.7 "Vail School" Cycle Charts for the Lower Jurassic, 1977-1988

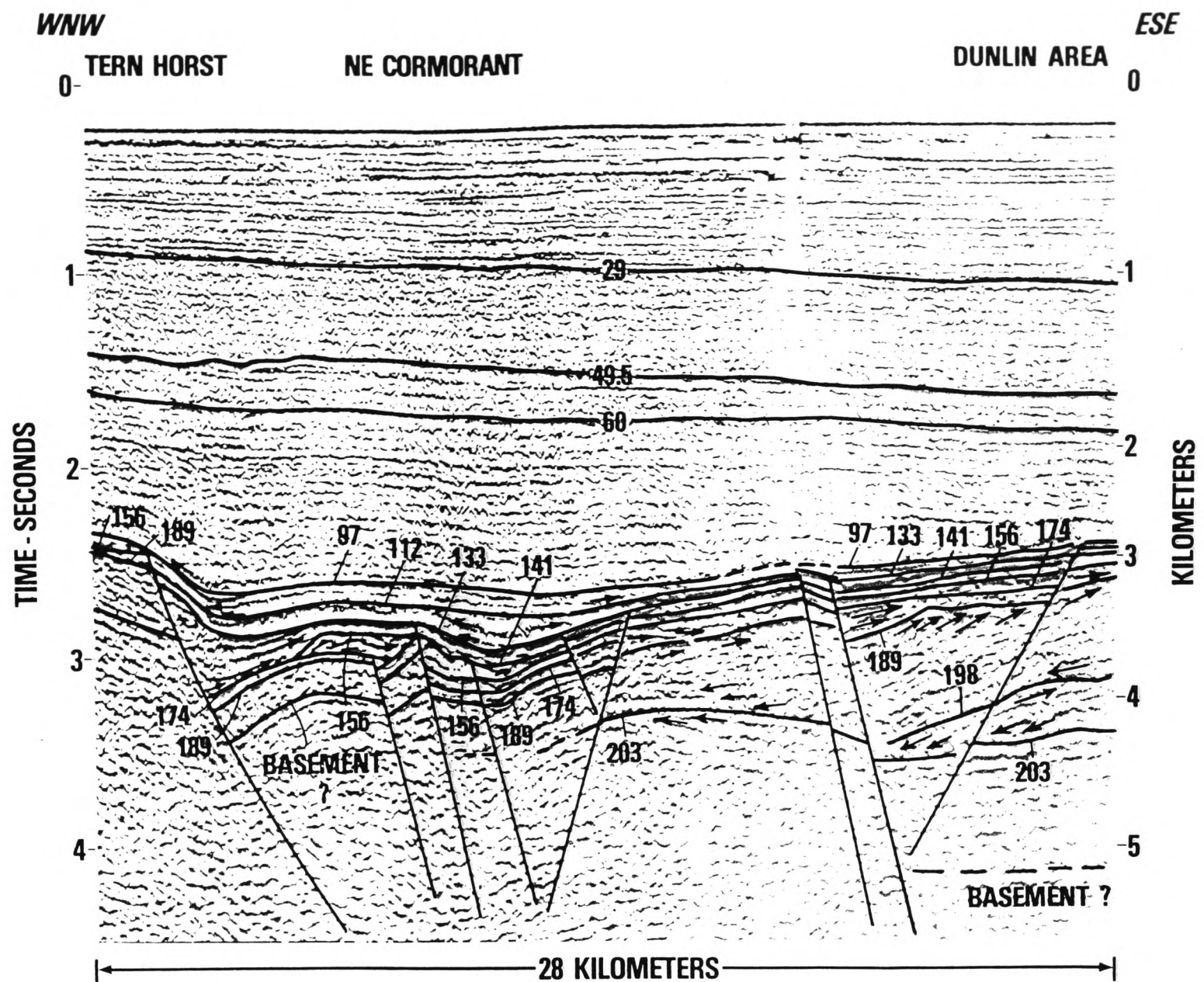


Figure 3.8 Seismic resolution in the Lower Jurassic of the North Viking Graben. "189" is near the base of the Sinemurian and "174" is near the top of the Dunlin Group (from Vail and Todd, 1981).

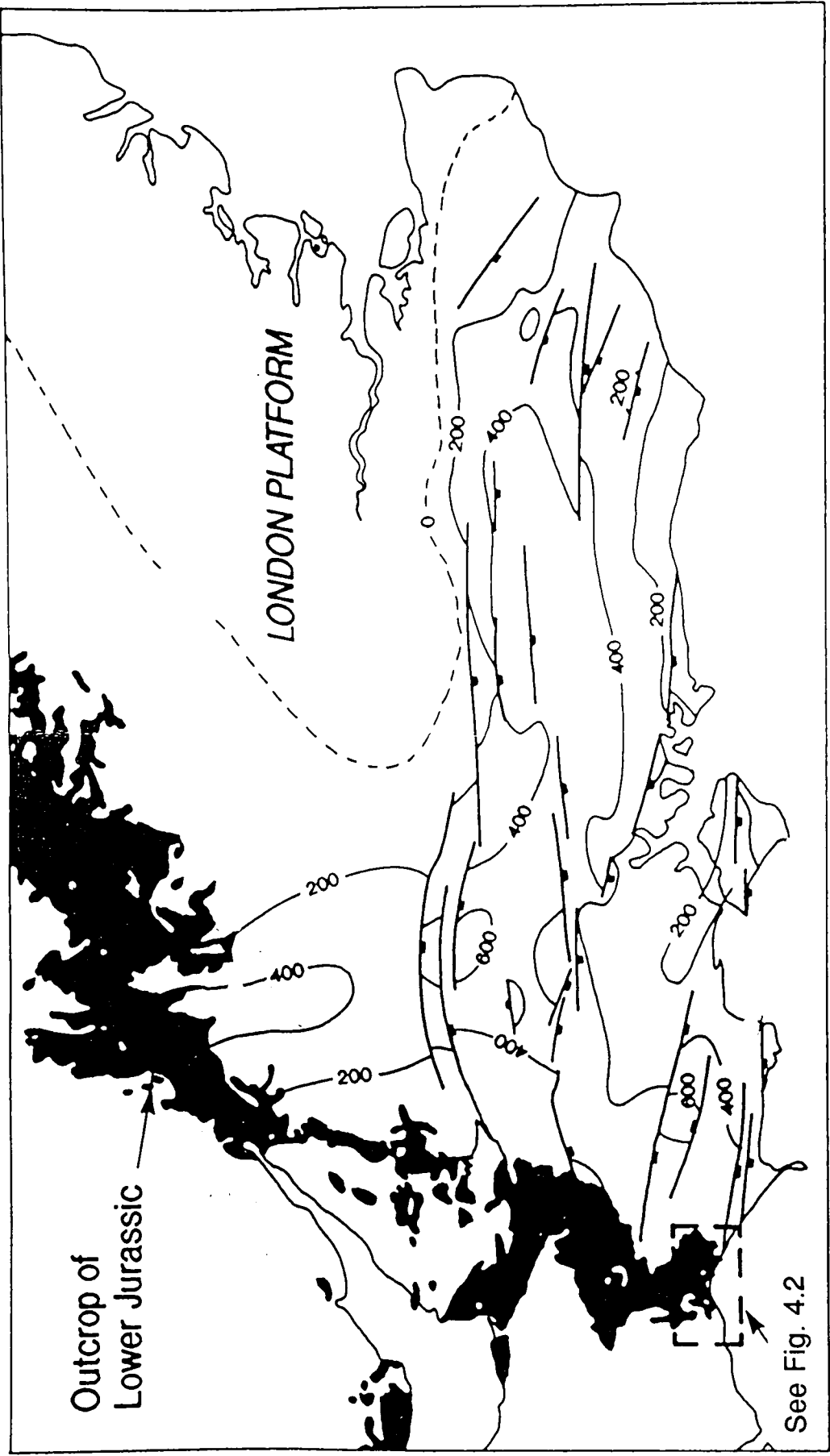


Figure 4.1 The Wessex Basin: Lower Jurassic Outcrop and Isopach (in metres, after Whittaker (ed.), 1985)

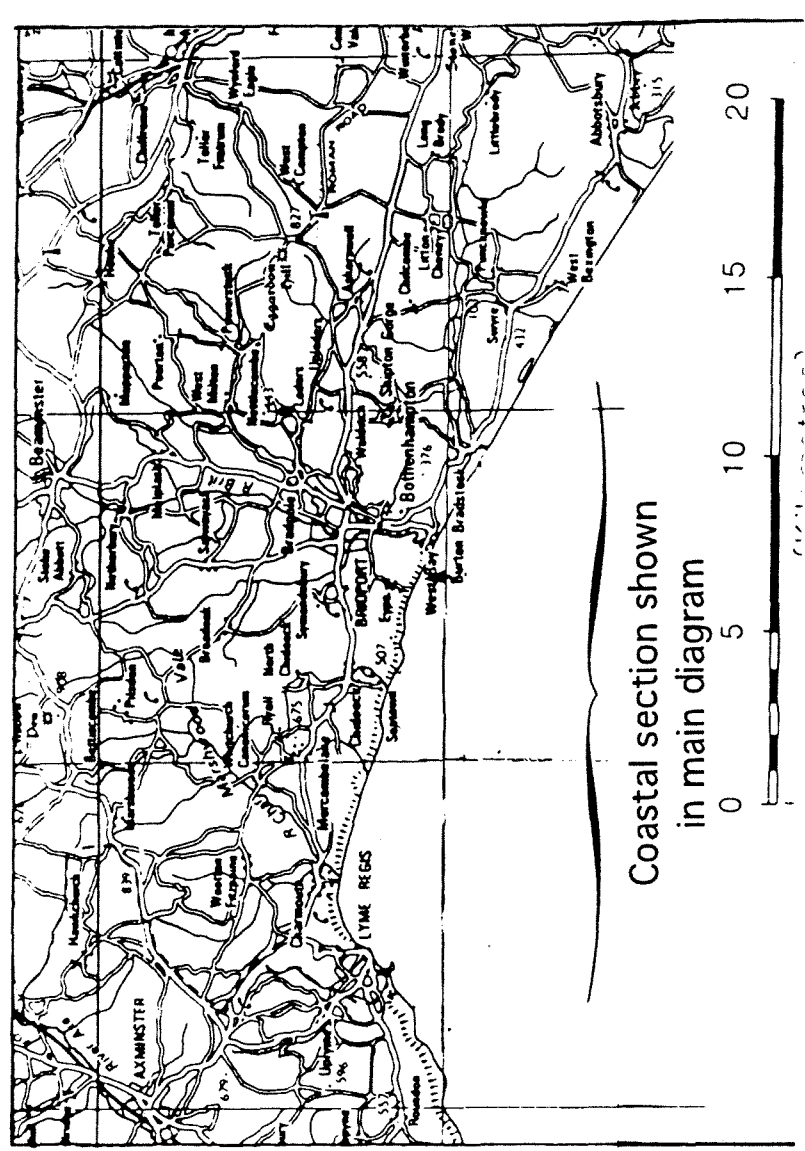
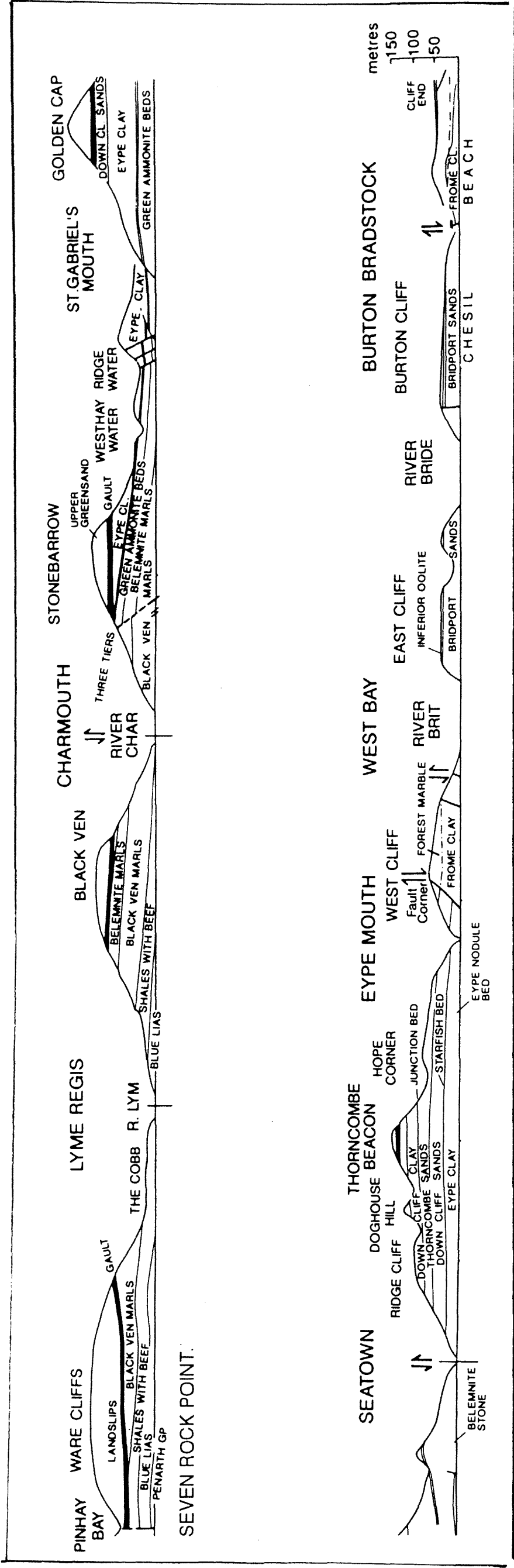


Figure 4.2 Location diagram for the Dorset Coast (after House, 1989 and Arkell, 1933)



Figure 4.3 The Blue Lias at outcrop: Seven Rock Point, Lyme Regis (see fig. 4.2)



Figure 4.4 The Black Ven Marls at outcrop: foreshore beneath Black Ven (see fig. 4.2)

Seven Rock Point, Lyme Regis

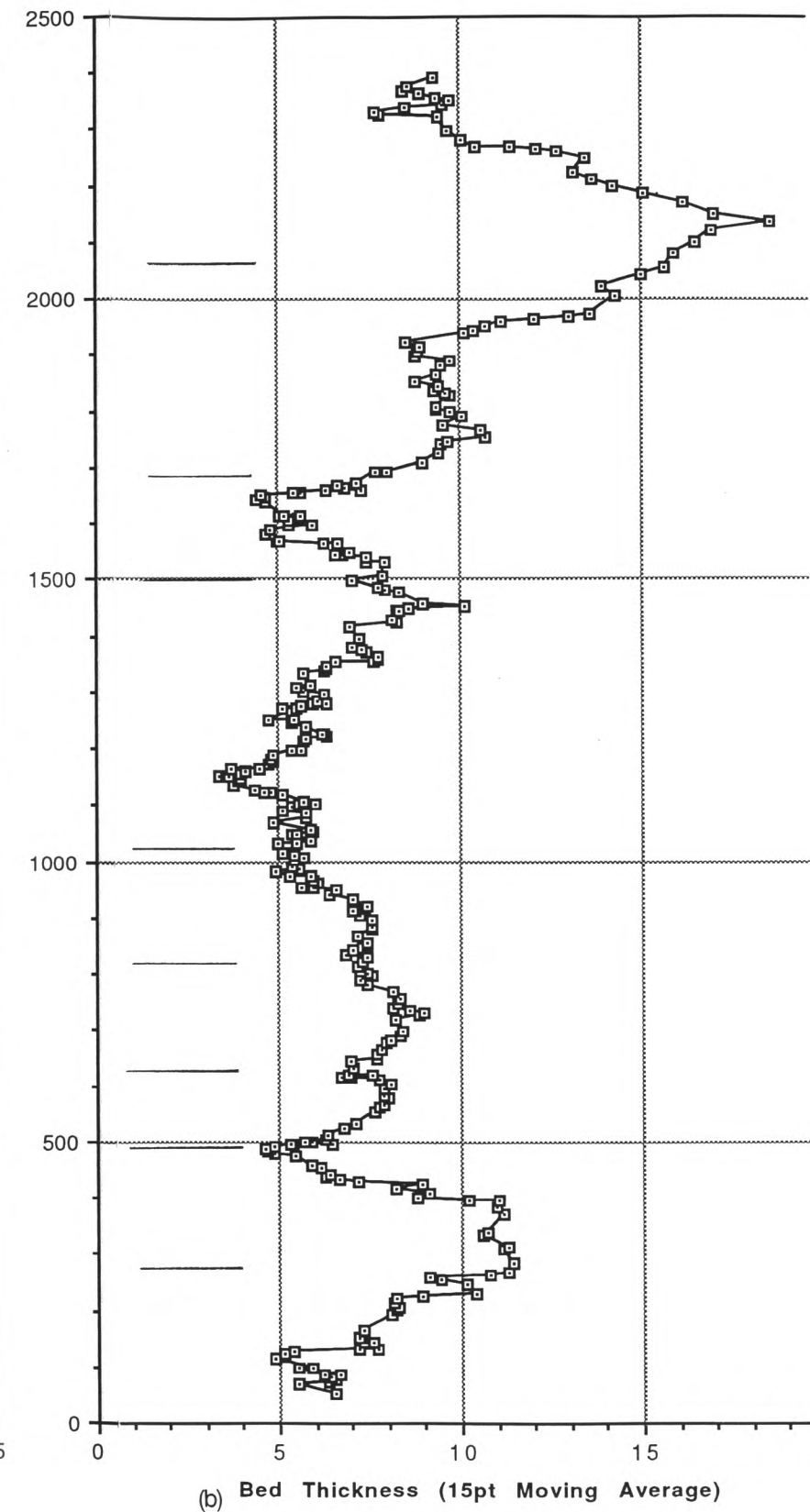
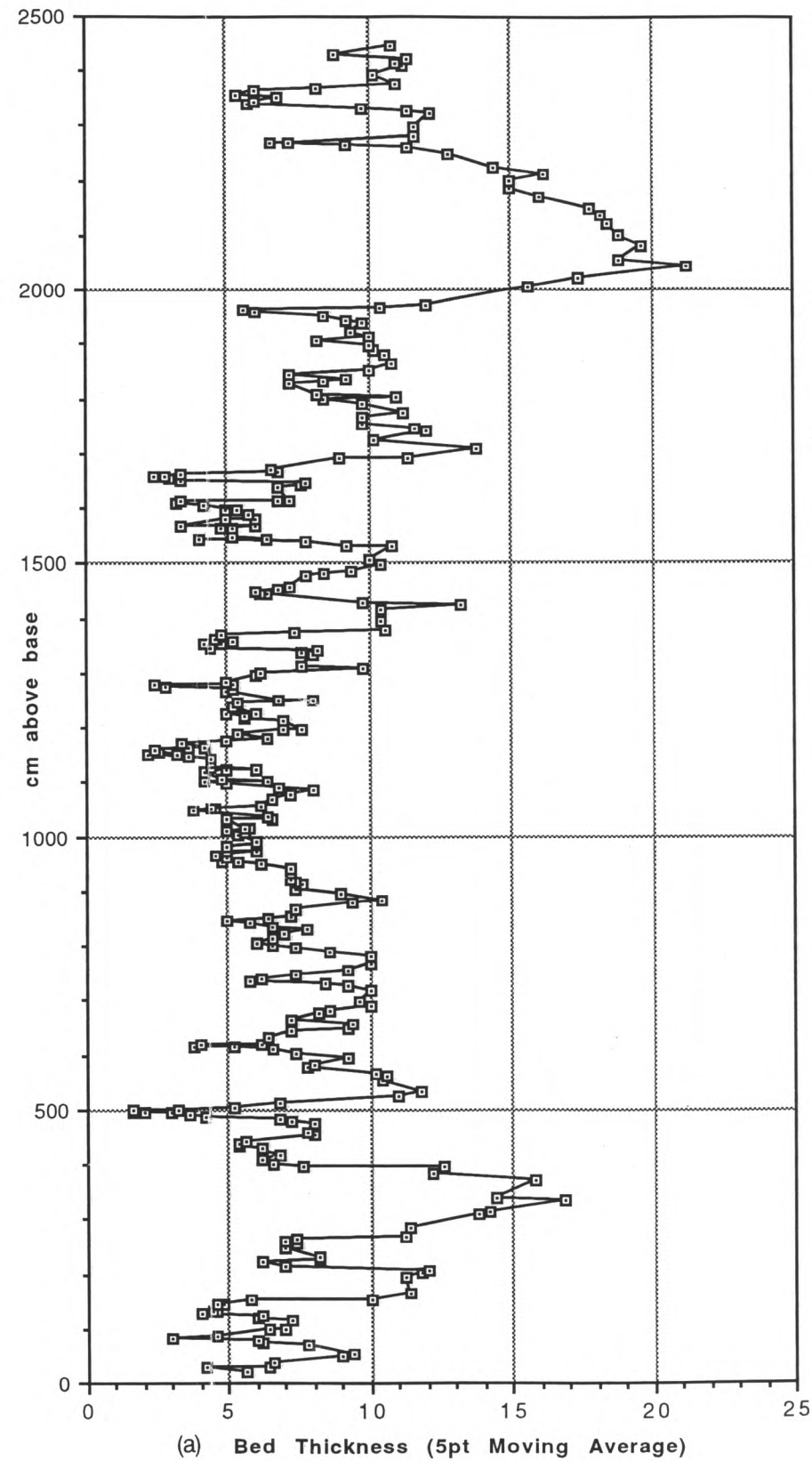
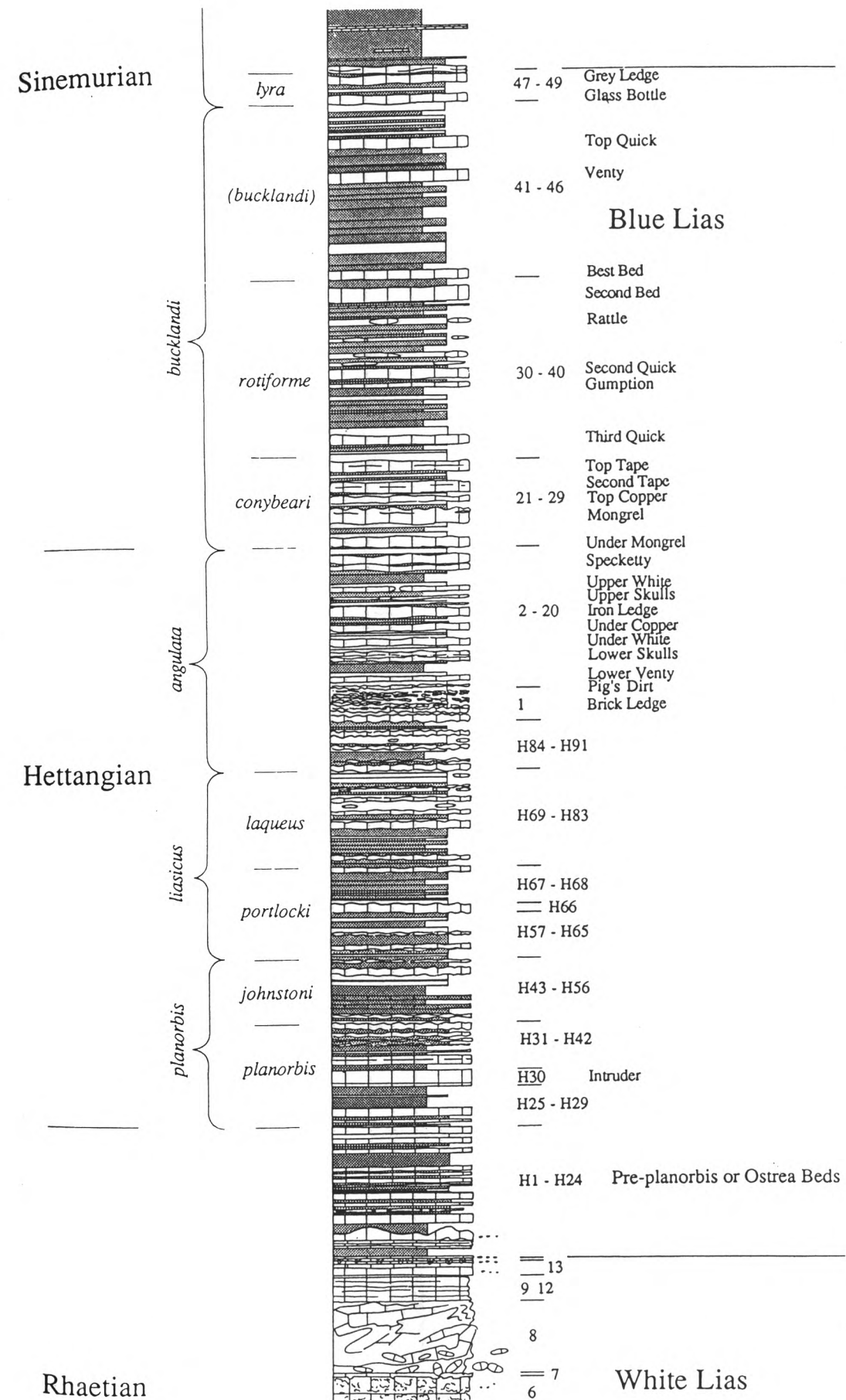


Figure 4.5 Log of the Blue Lias with bed spacing data smoothed using (a) 5-point, and (b) 15-point moving averages

Seven Rock Point, Lyme Regis

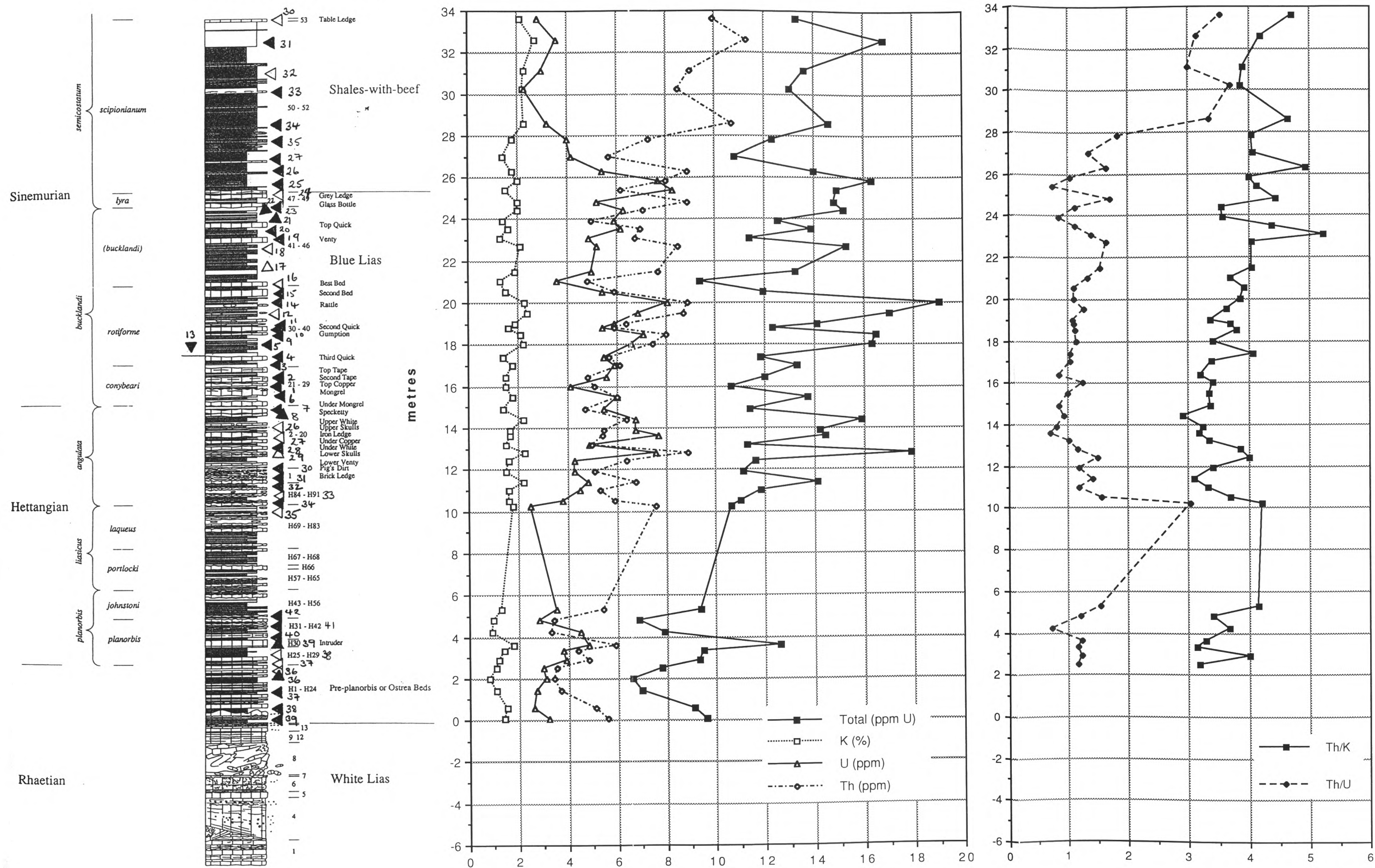


Figure 4.6 Blue Lias spectral gamma-ray data. Stratigraphic log from Hesselbo & Jenkyns (in press); see Appendix 1 for symbols used to describe gamma-ray measurement stations and for tabulated data.

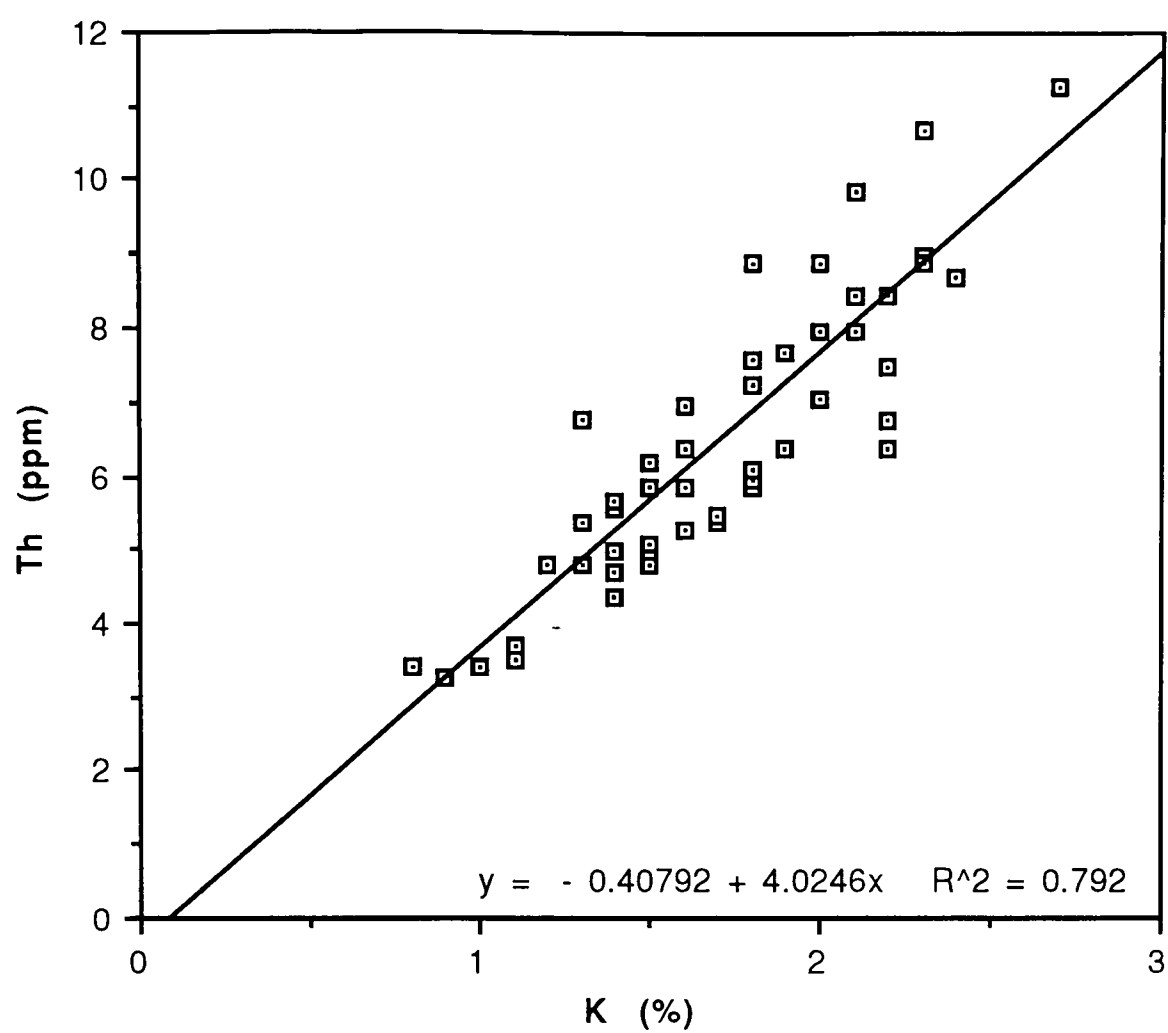


Figure 4.7a Thorium v. Potassium for the Blue Lias

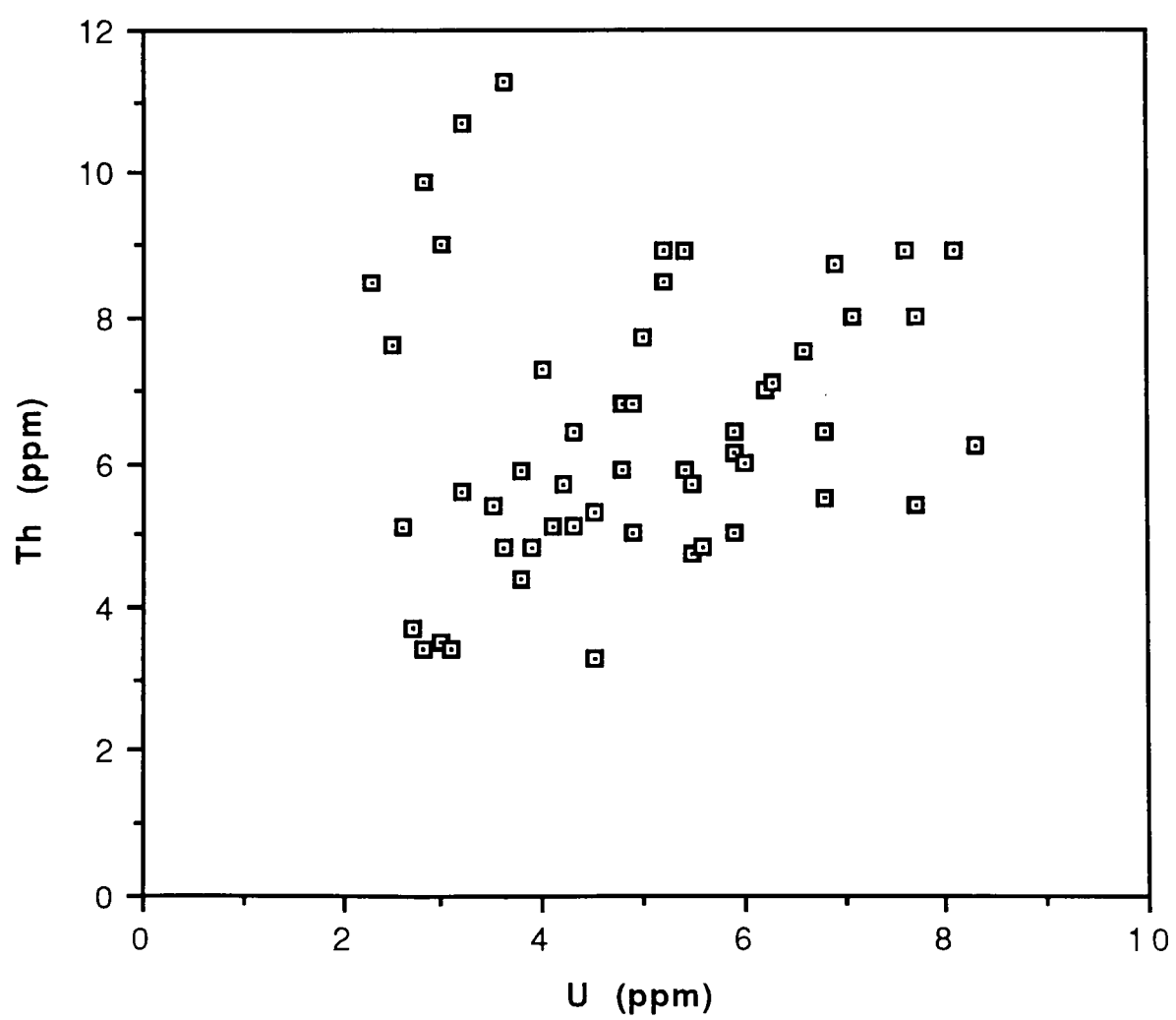


Figure 4.7b Thorium v. Uranium for the Blue Lias

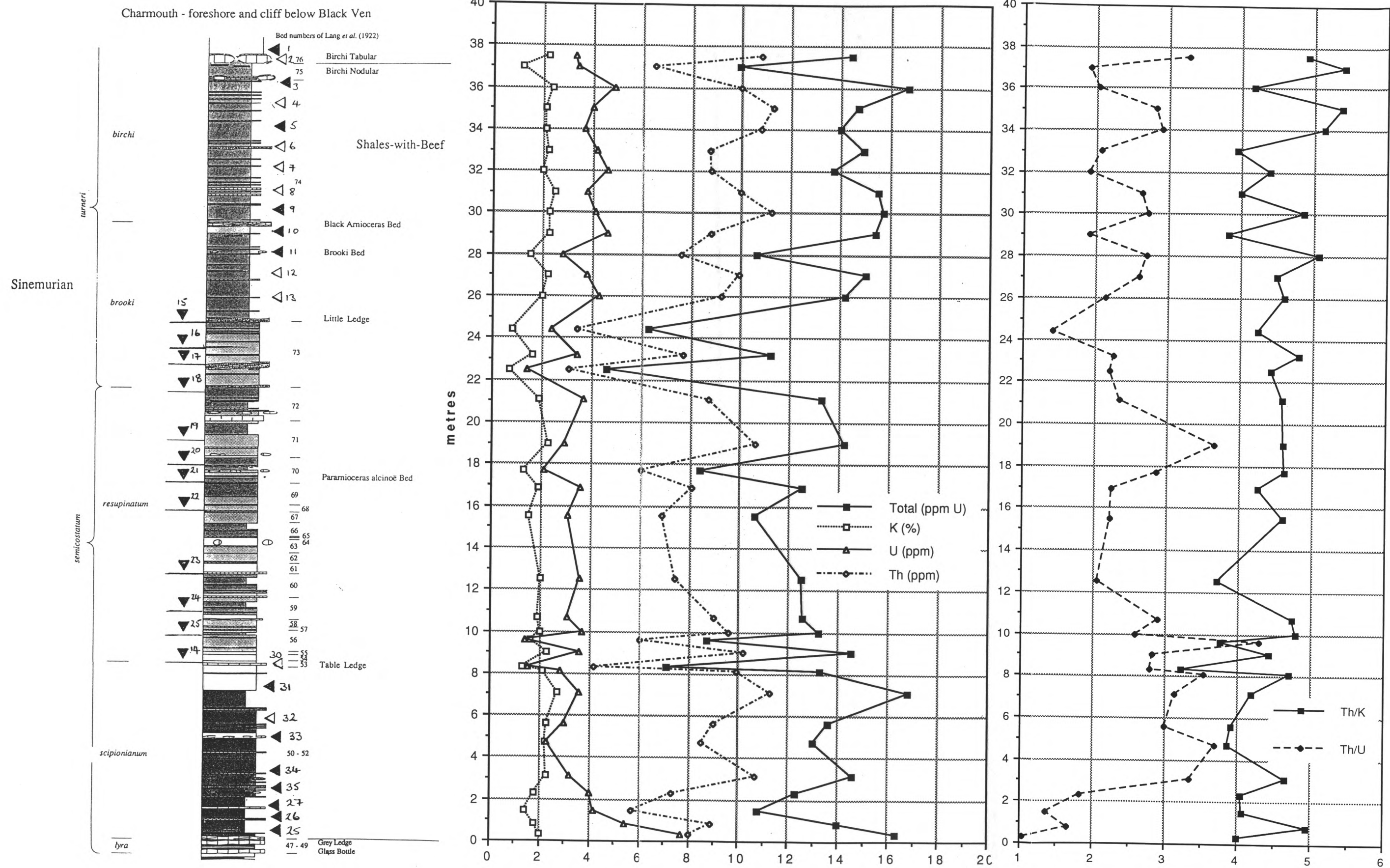


Figure 4.8 Shales-with-Beef spectral gamma-ray data. Stratigraphic log from Hesselbo & Jenkyns (in press); see Appendix 1 for symbols used to describe gamma-ray measurement stations and for tabulated data.

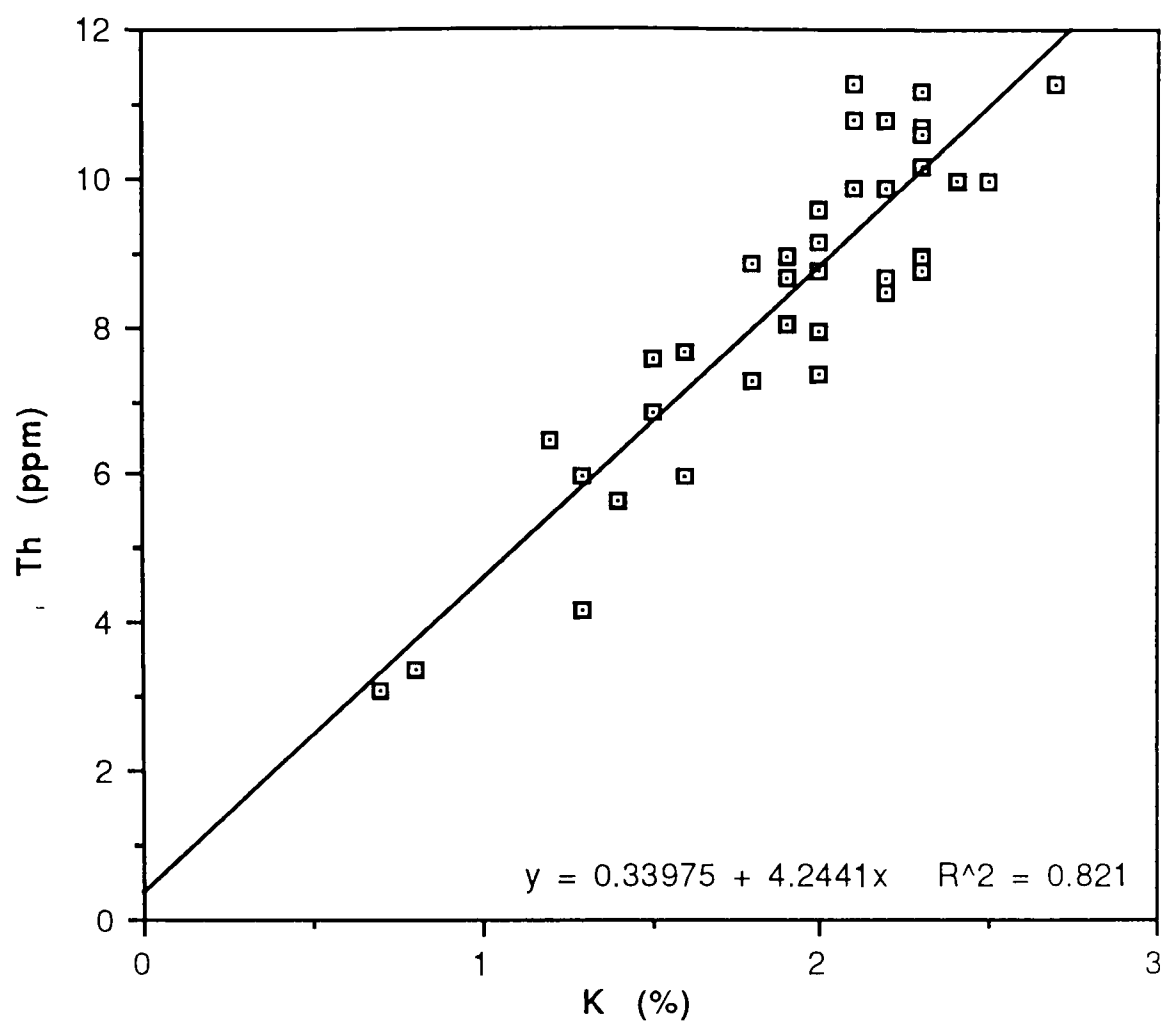


Figure 4.9a Thorium v. Potassium for the Shales-with-Beef

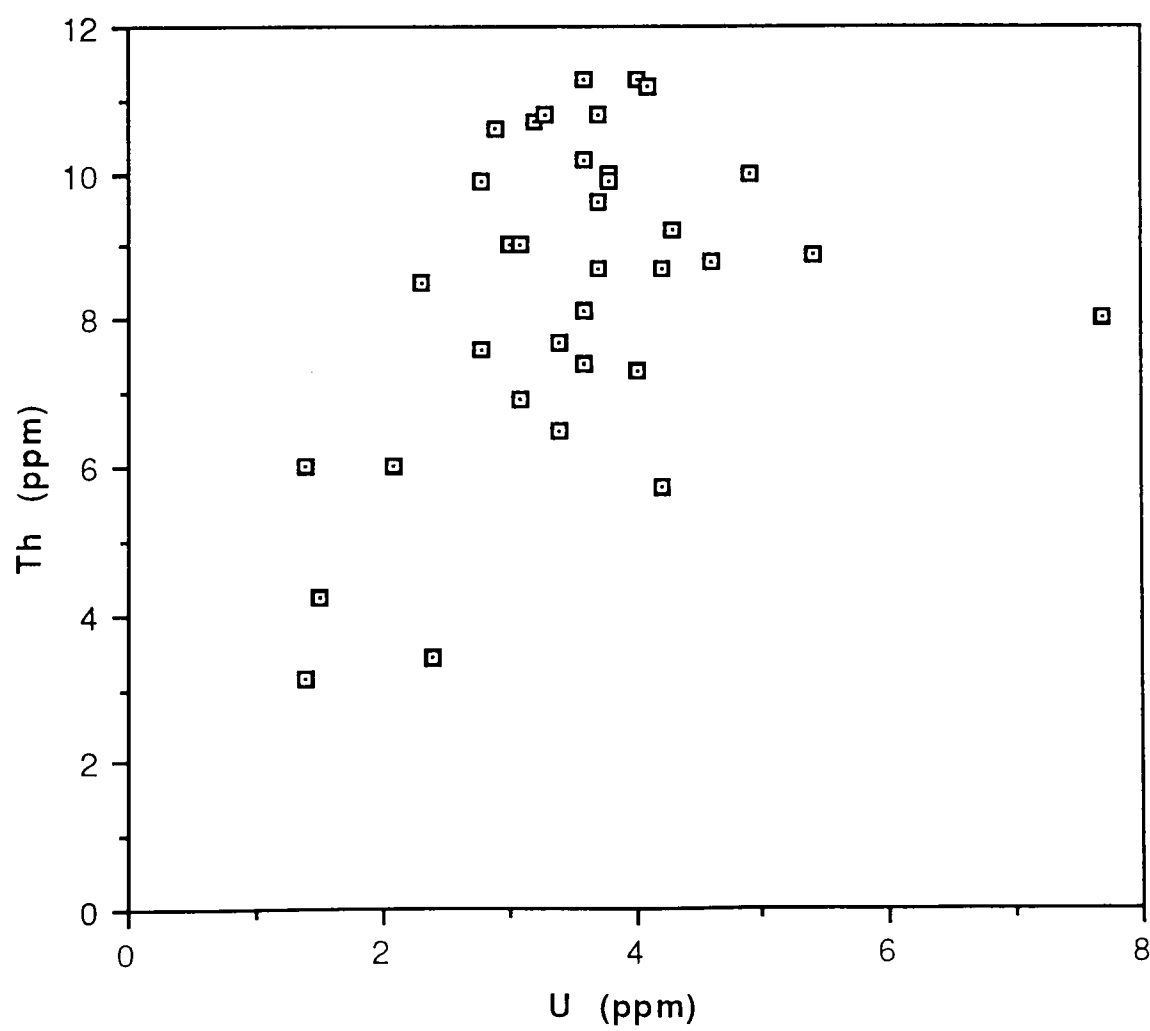


Figure 4.9b Thorium v. Uranium for the Shales-with-Beef

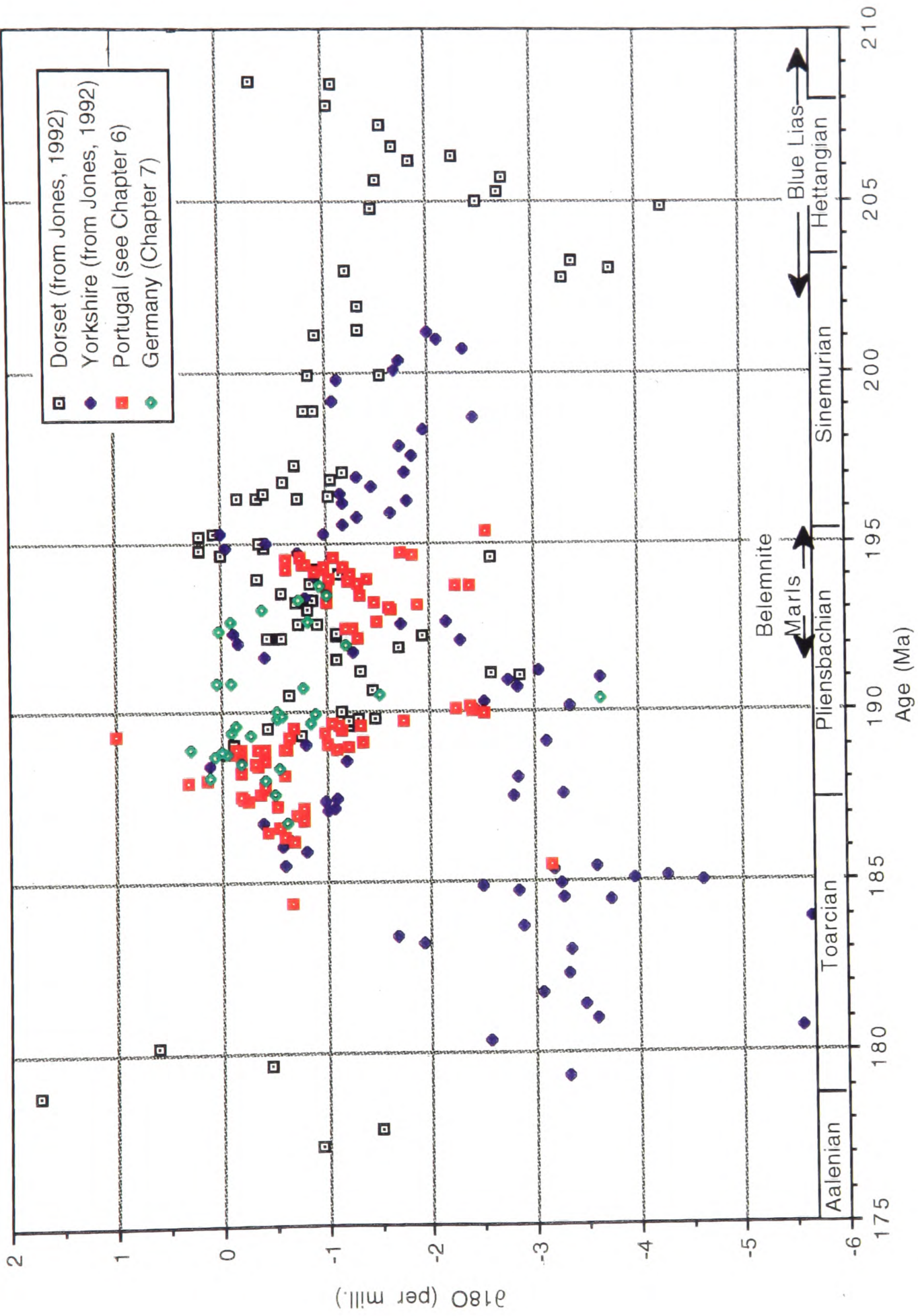
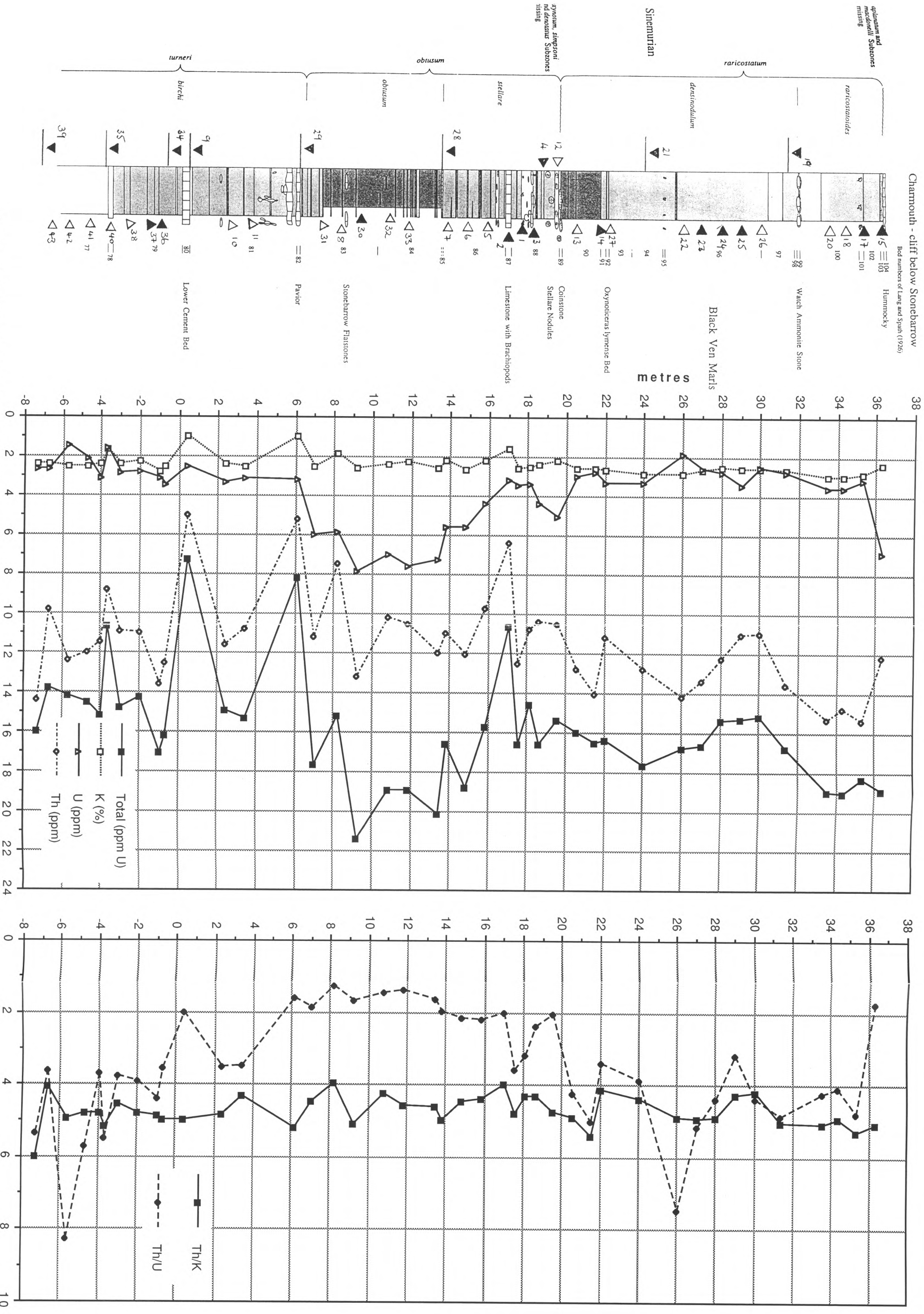


Figure 4.10 Oxygen Isotope Data from Lower Jurassic Skeletal Carbonate



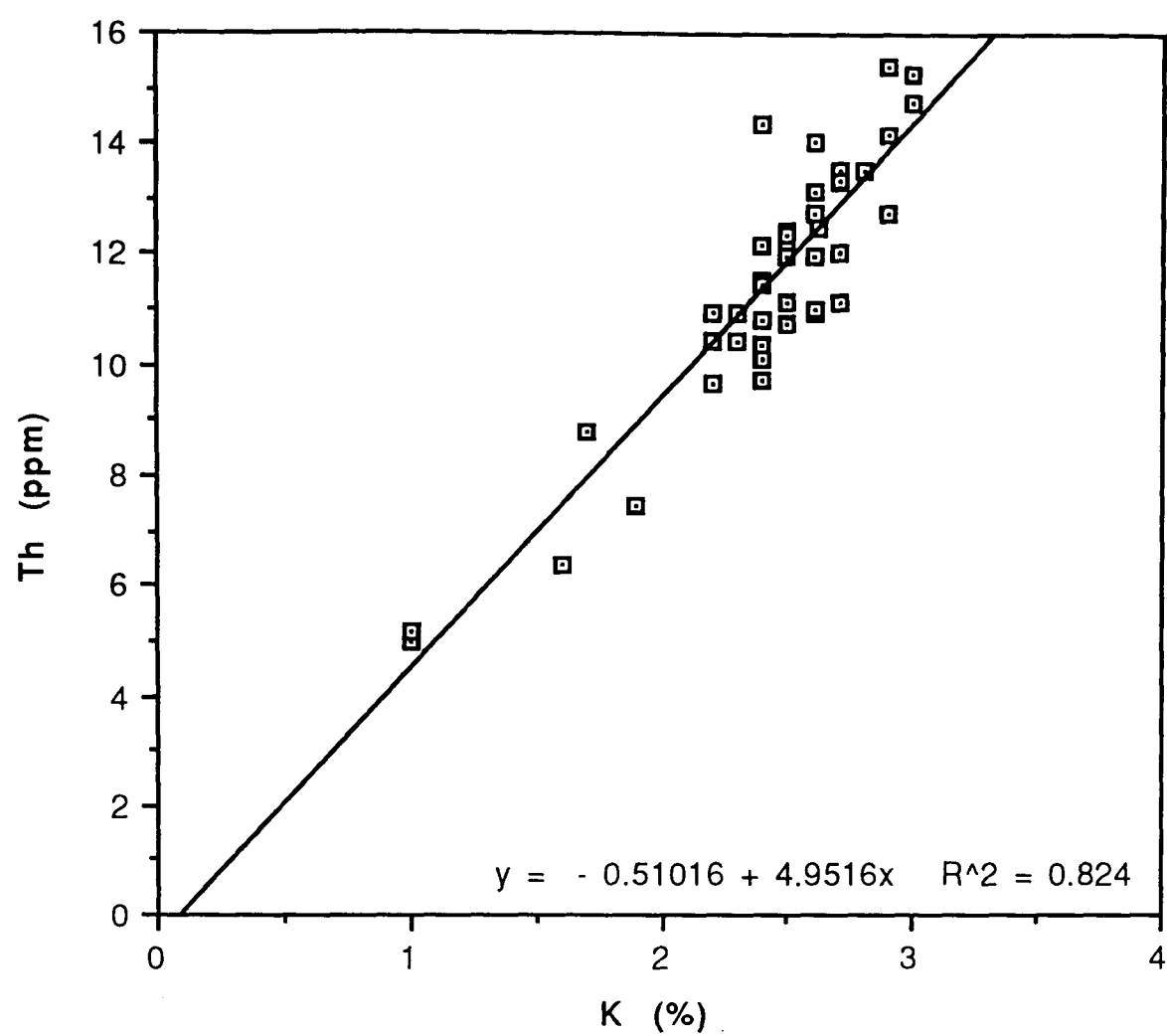


Figure 4.12a Thorium v. Potassium for the Black Ven Marls

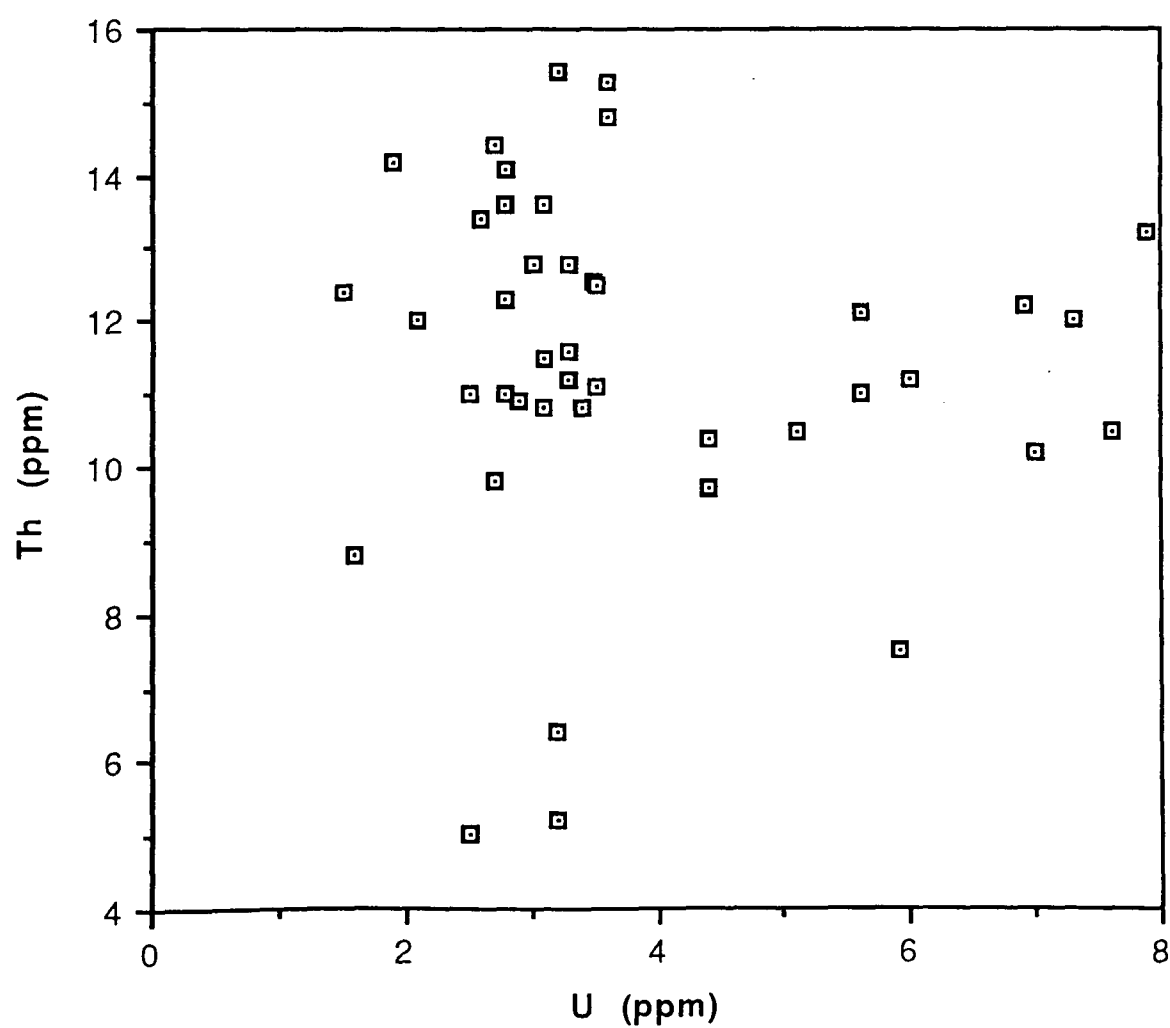


Figure 4.12b Thorium v. Uranium for the Black Ven Marls

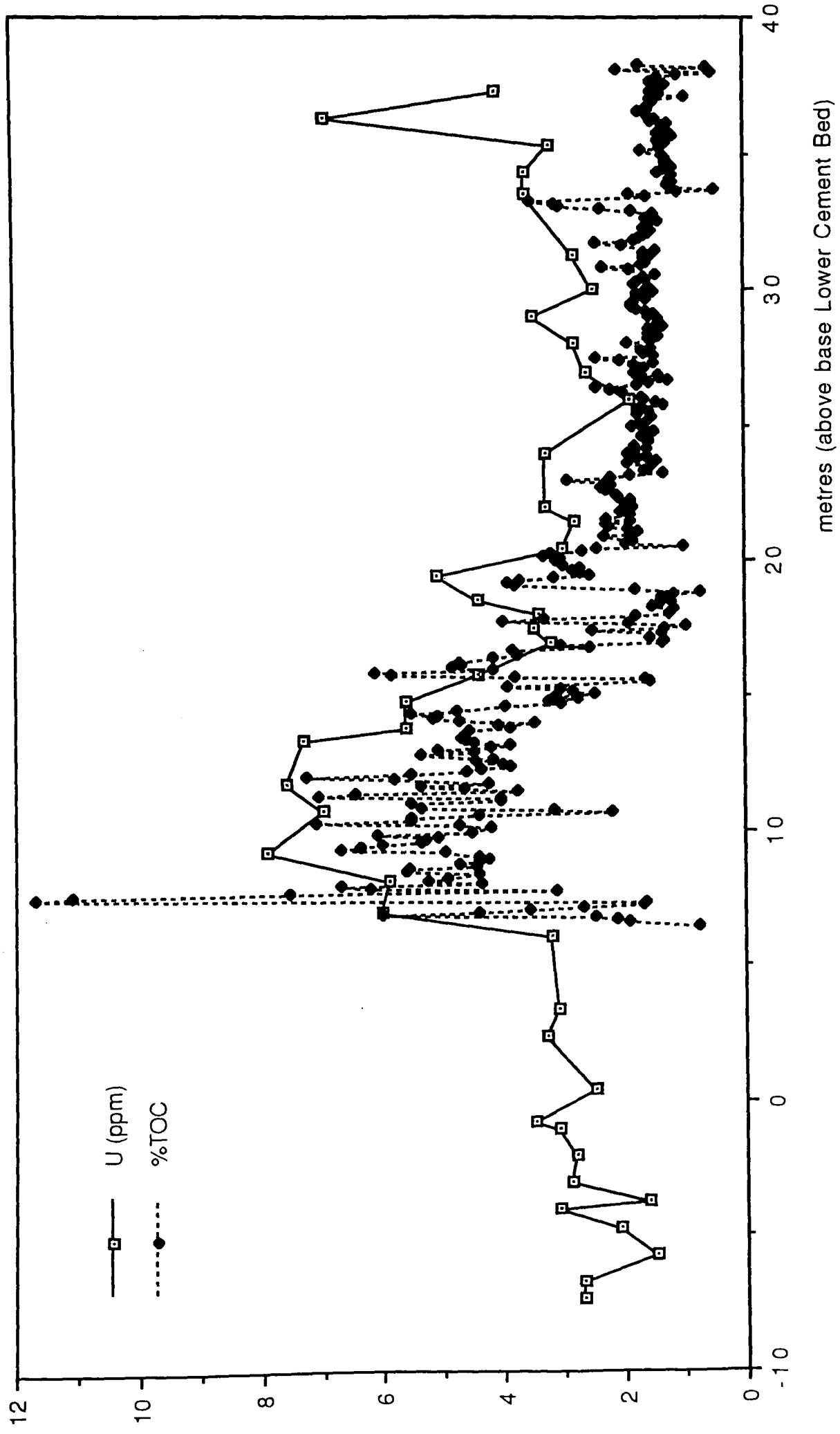


Figure 4.13 Comparison of Uranium and Total Organic Carbon measurements for the Black Ven Marls
(Unpublished TOC data courtesy of H. C. Jenkins)

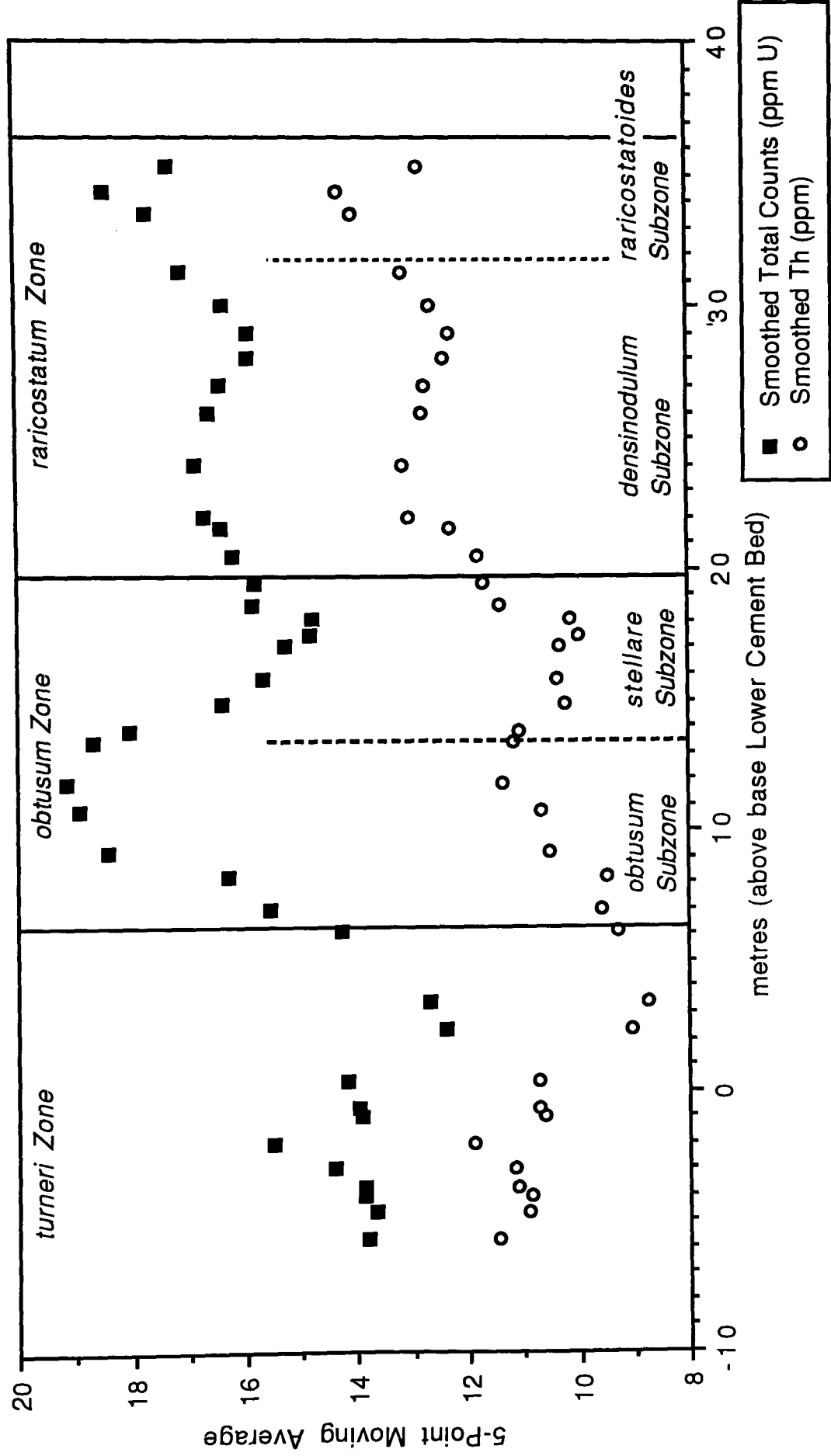


Figure 4.14 Smoothed Spectral Gamma-Ray Data for the Black Ven Marls



Figure 4.15 The Belemnite Marls below Stonebarrow, Dorset (fig. 4.2). Note the upwards-tightening of limestone-marl rhythms.



Figure 4.16a The Belemnite Bed near St. Gabriel's Mouth, Dorset (see fig. 4.2)

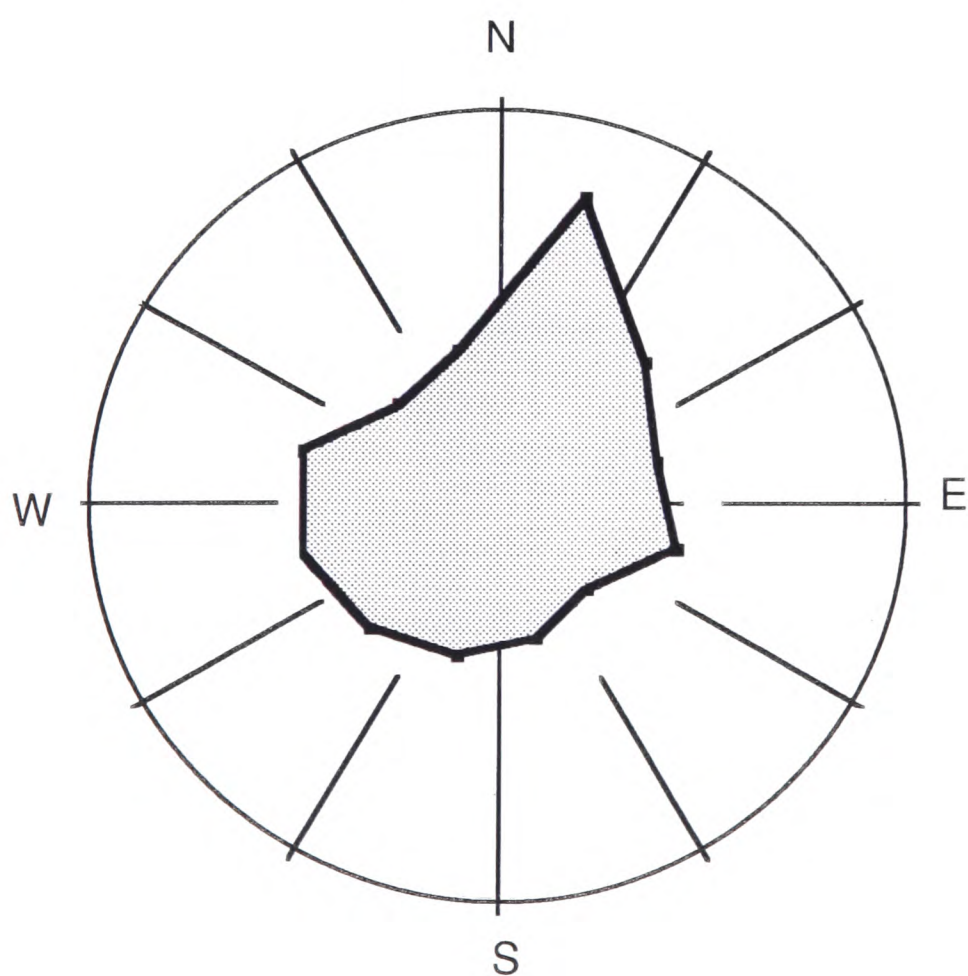


Figure 4.16b Orientation of 108 randomly selected belemnites from the Belemnite Bed, Dorset (Belemnite Guards point in direction plotted, ie the most common pointing direction is towards 015 degrees).

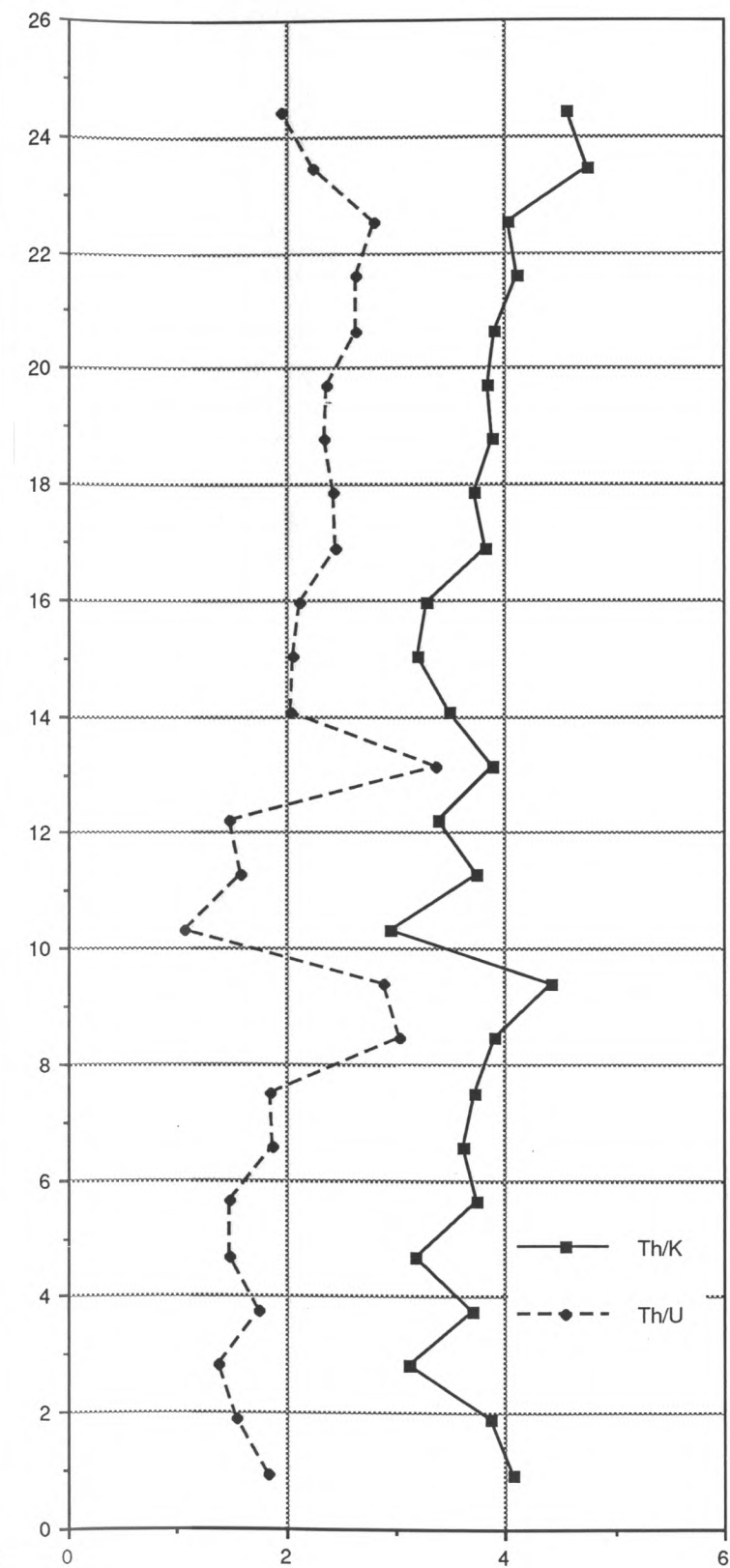
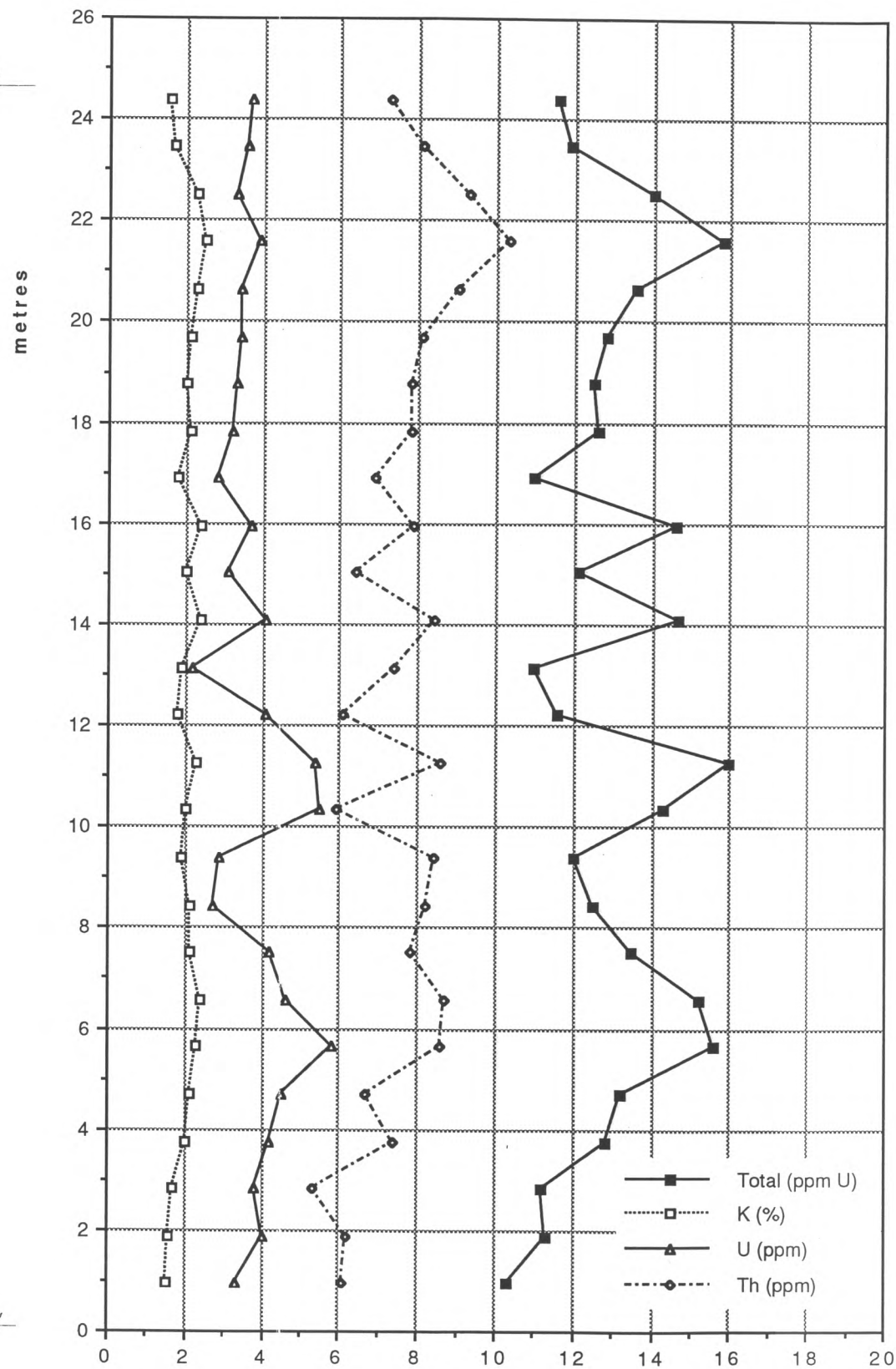
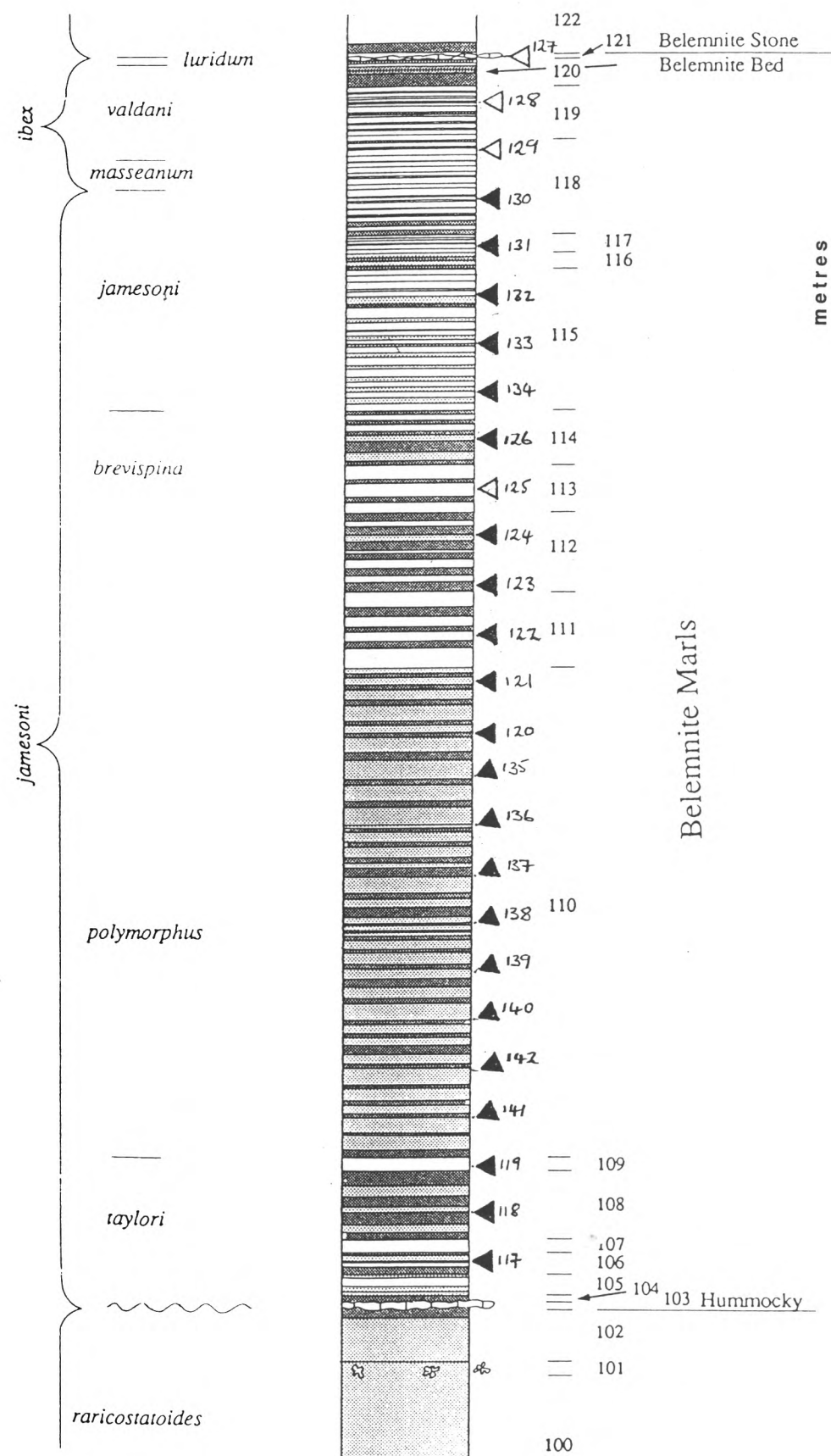


Figure 4.17 Belemnite Marls spectral gamma-ray data. Stratigraphic log from Hesselbo & Jenkyns (in press); see Appendix 1 for symbols used to describe gamma-ray measurement stations and for tabulated data.

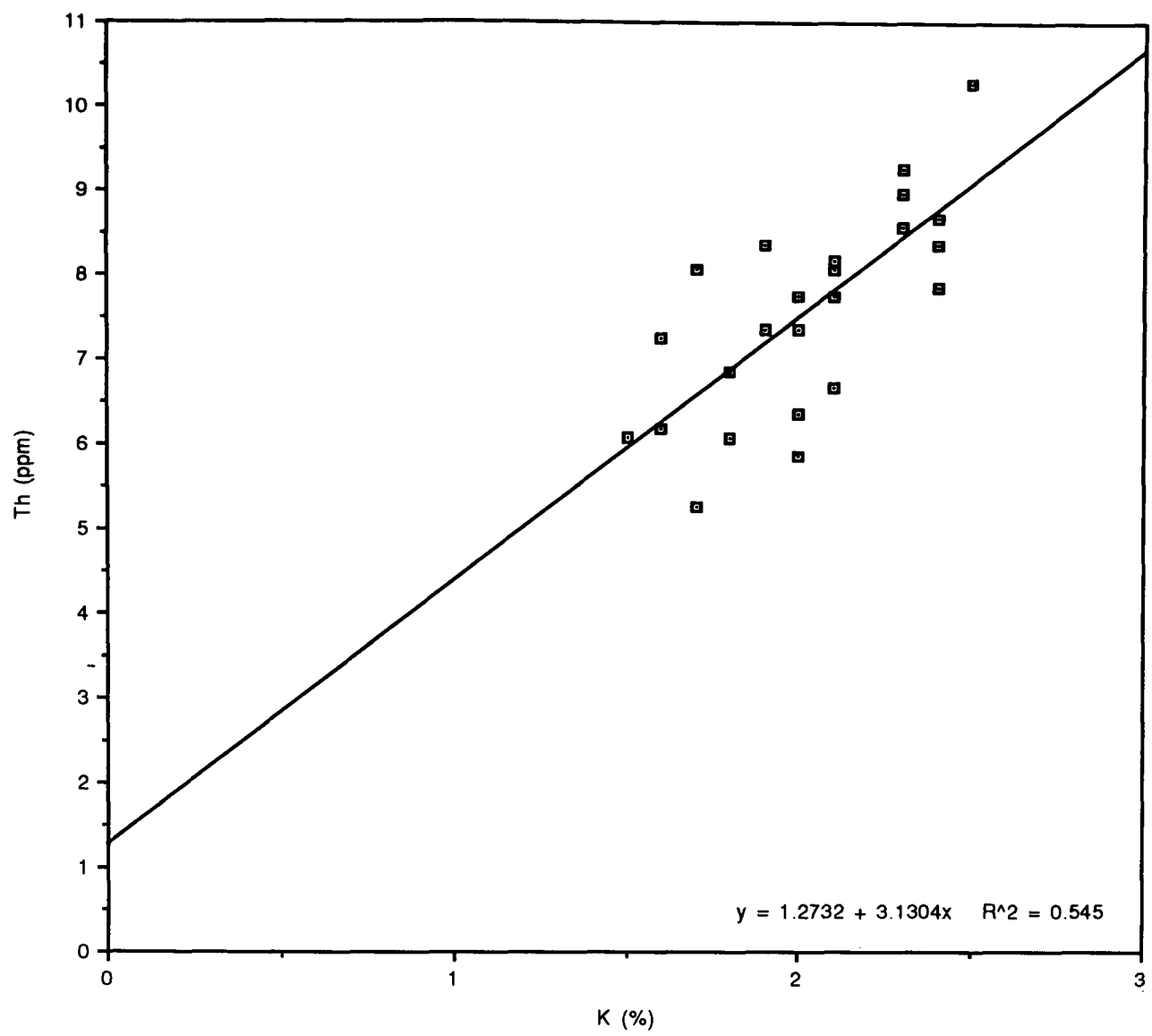


Figure 4.18a Thorium v. Potassium for the Belemnite Marls

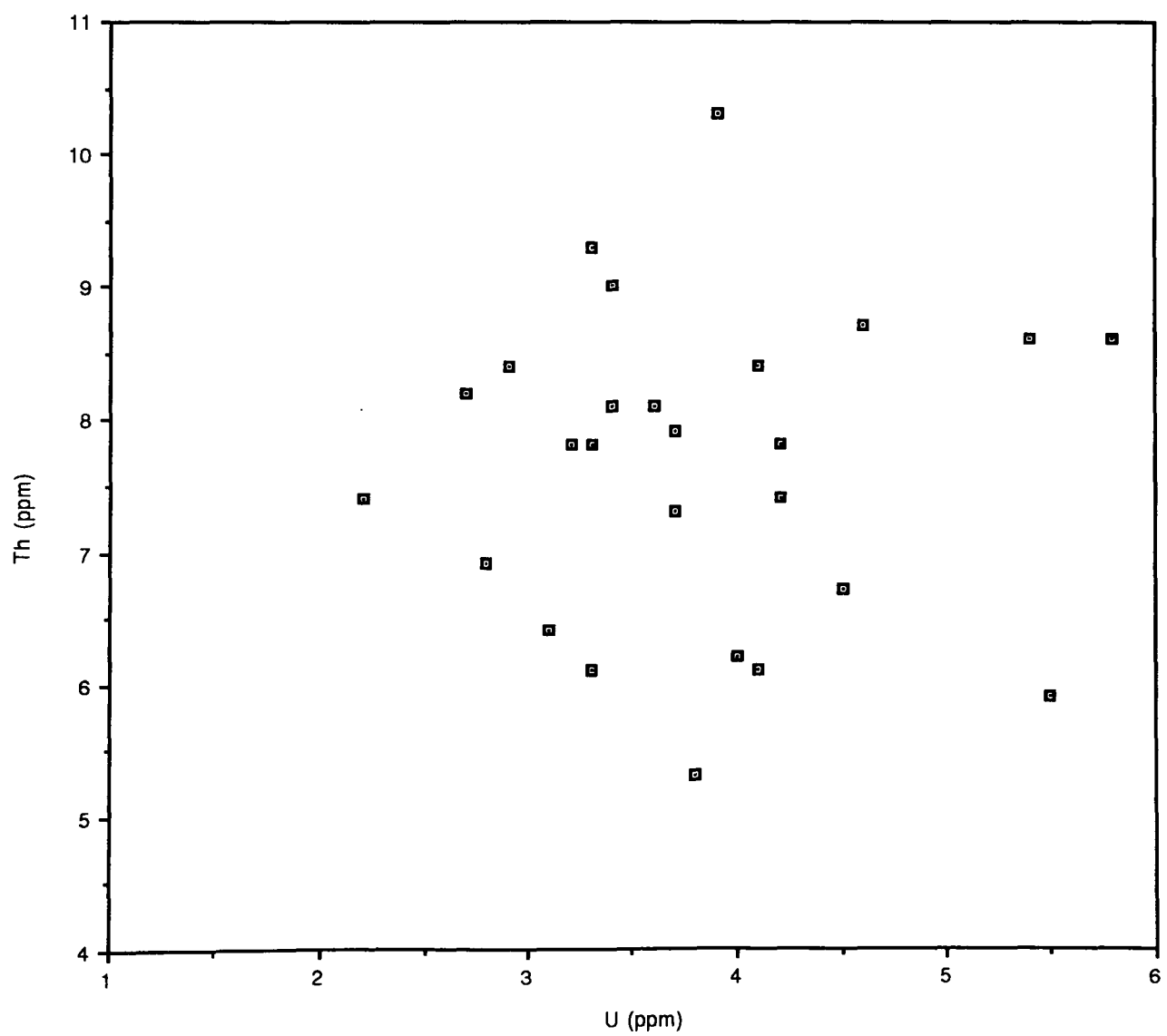


Figure 4.18b Thorium v. Uranium for the Belemnite Marls

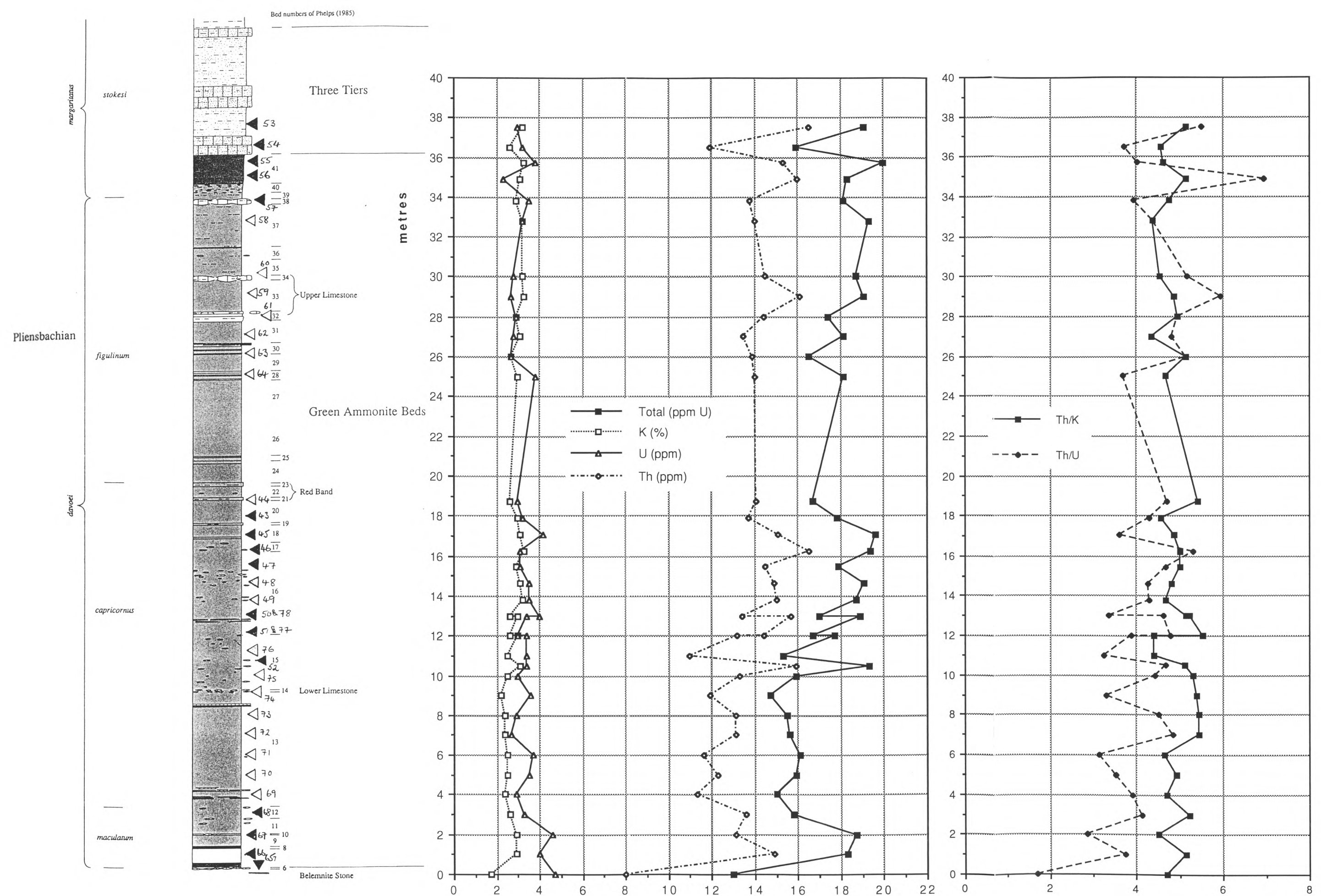


Figure 4.19 Green Ammonite Beds spectral gamma-ray data. Stratigraphic log from Hesselbo & Jenkyns (in press); see Appendix 1 for symbols used to describe gamma-ray measurement stations and for tabulated data.

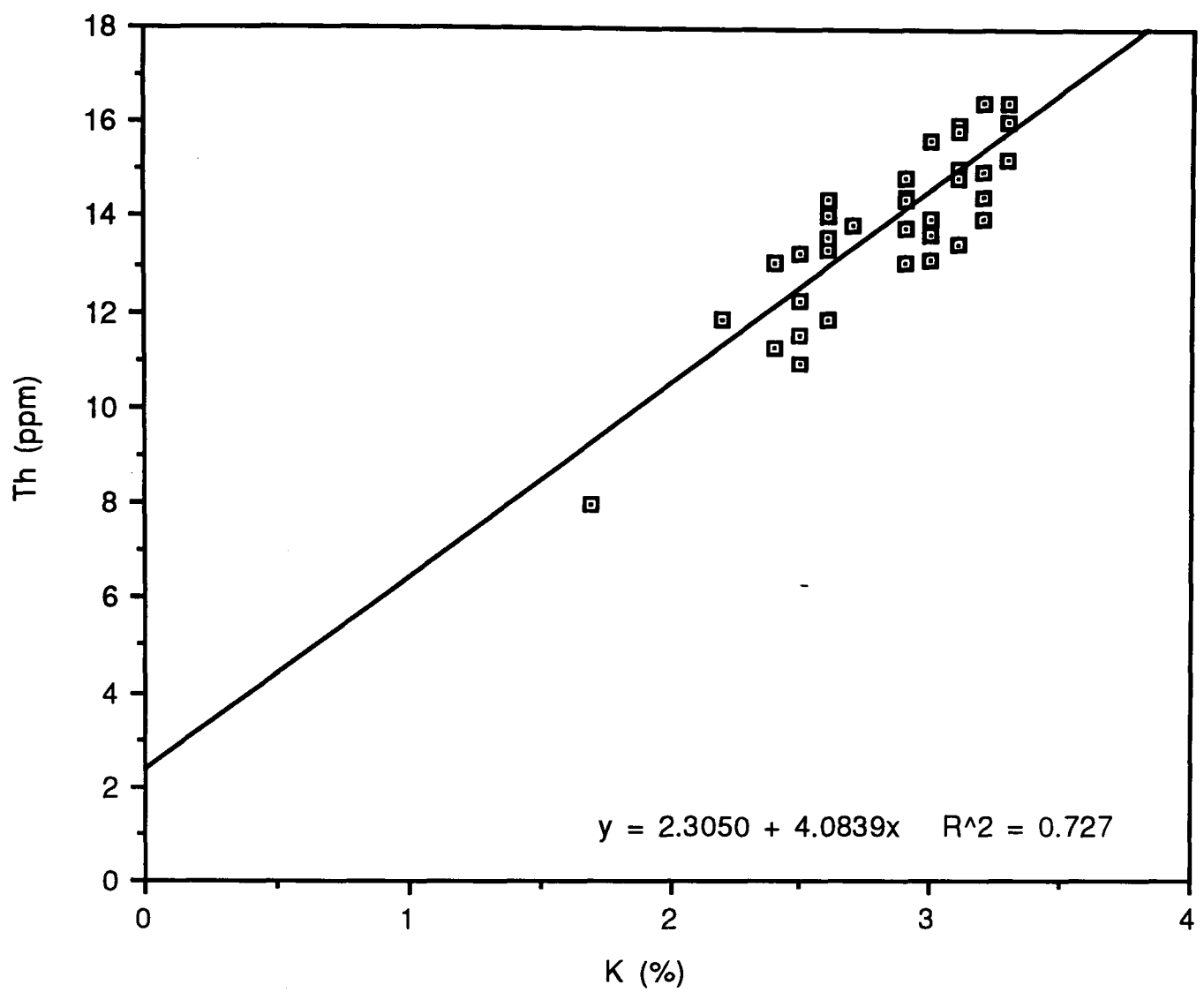


Figure 4.20a Thorium v. Potassium for the Green Ammonite Beds

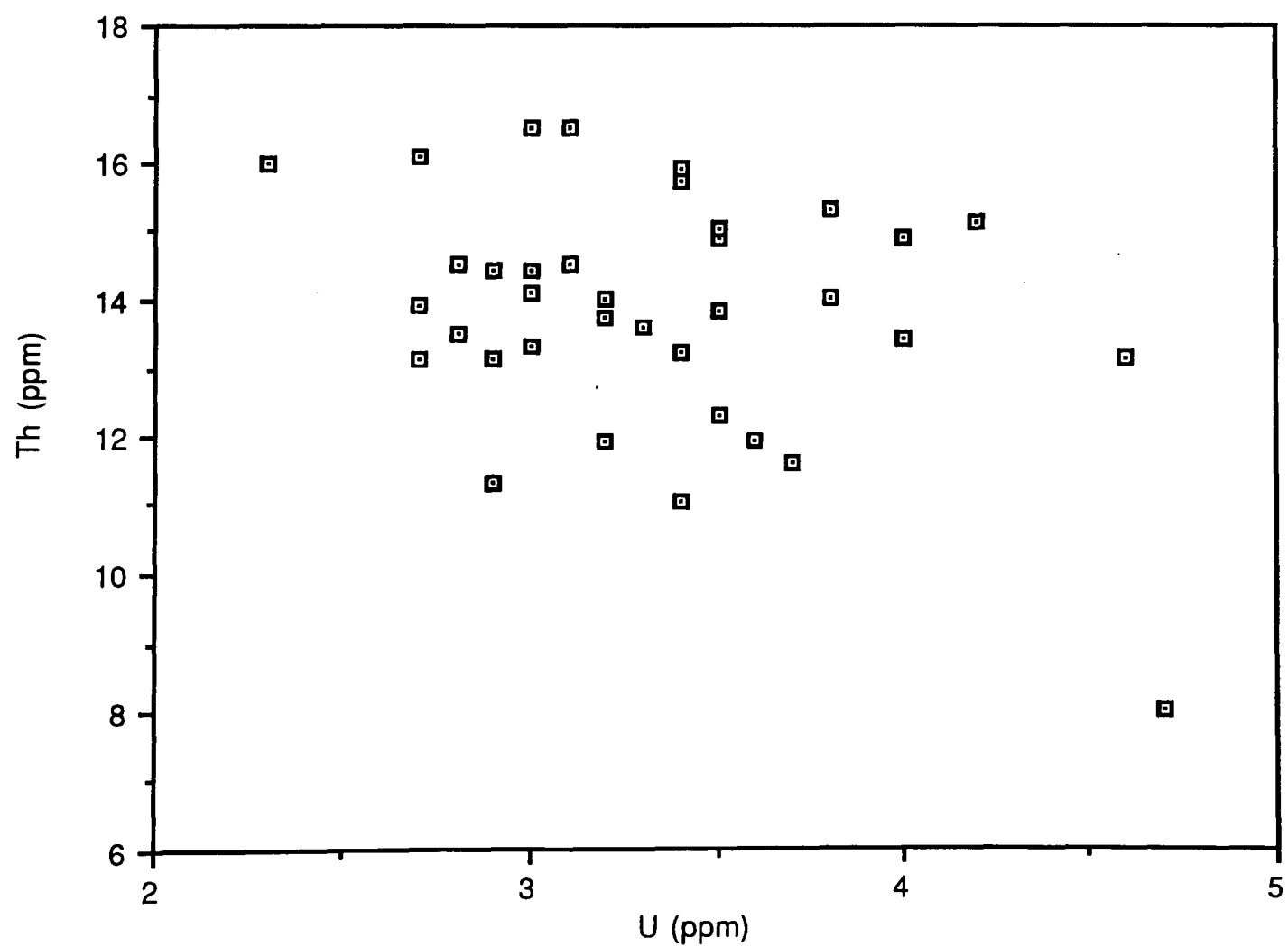


Figure 4.20b Thorium v. Uranium for the Green Ammonite Beds



Figure 4.21a Cliff below Golden Cap, Dorset (fig. 4.2). The Three Tiers form the metre-scale grey ledges in the centre of the photograph. These are overlain by the Eype Clay (grey) and the Down Cliff Sands (yellow).

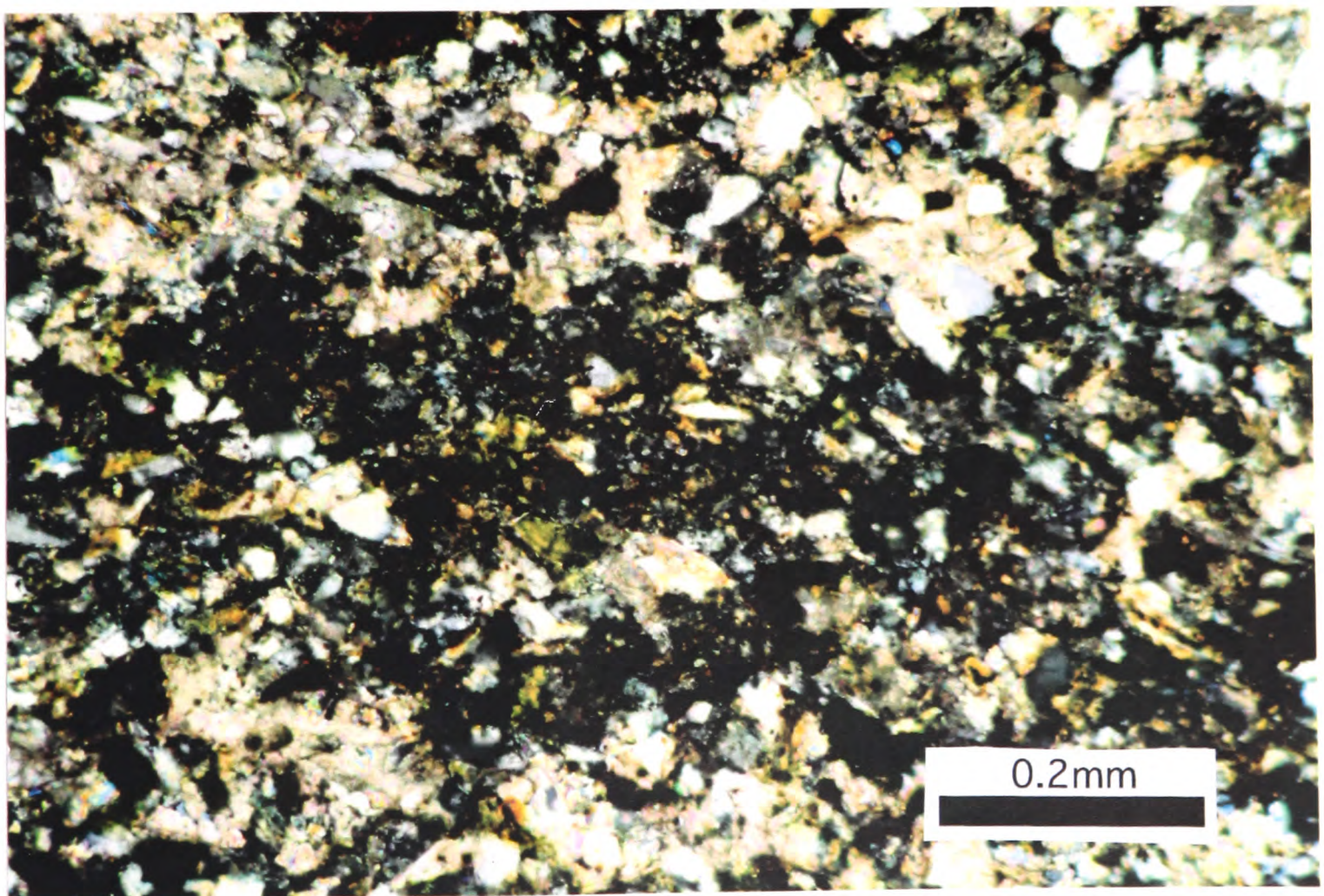


Figure 4.21b Photomicrograph (xpl) of argillaceous siltstone from the lowermost of the Three Tiers

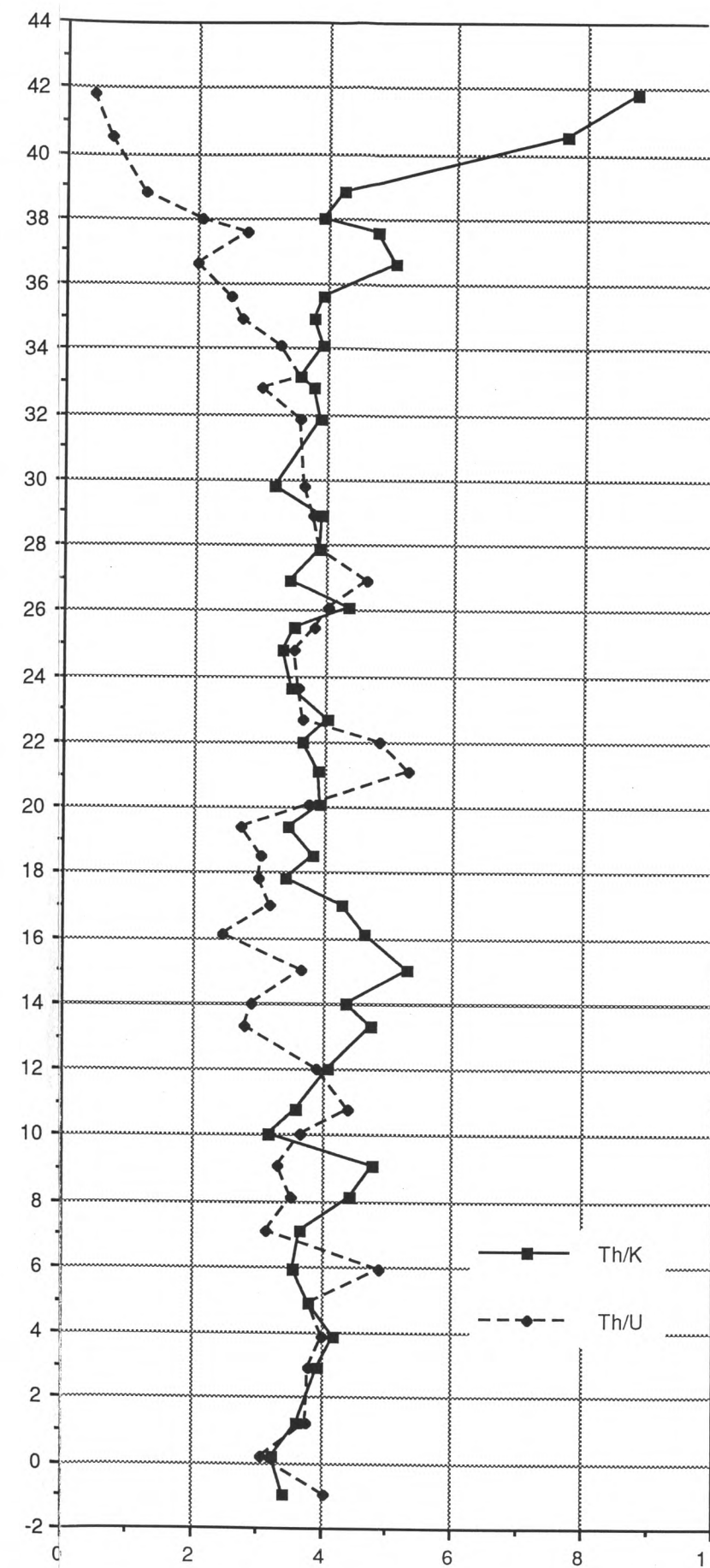
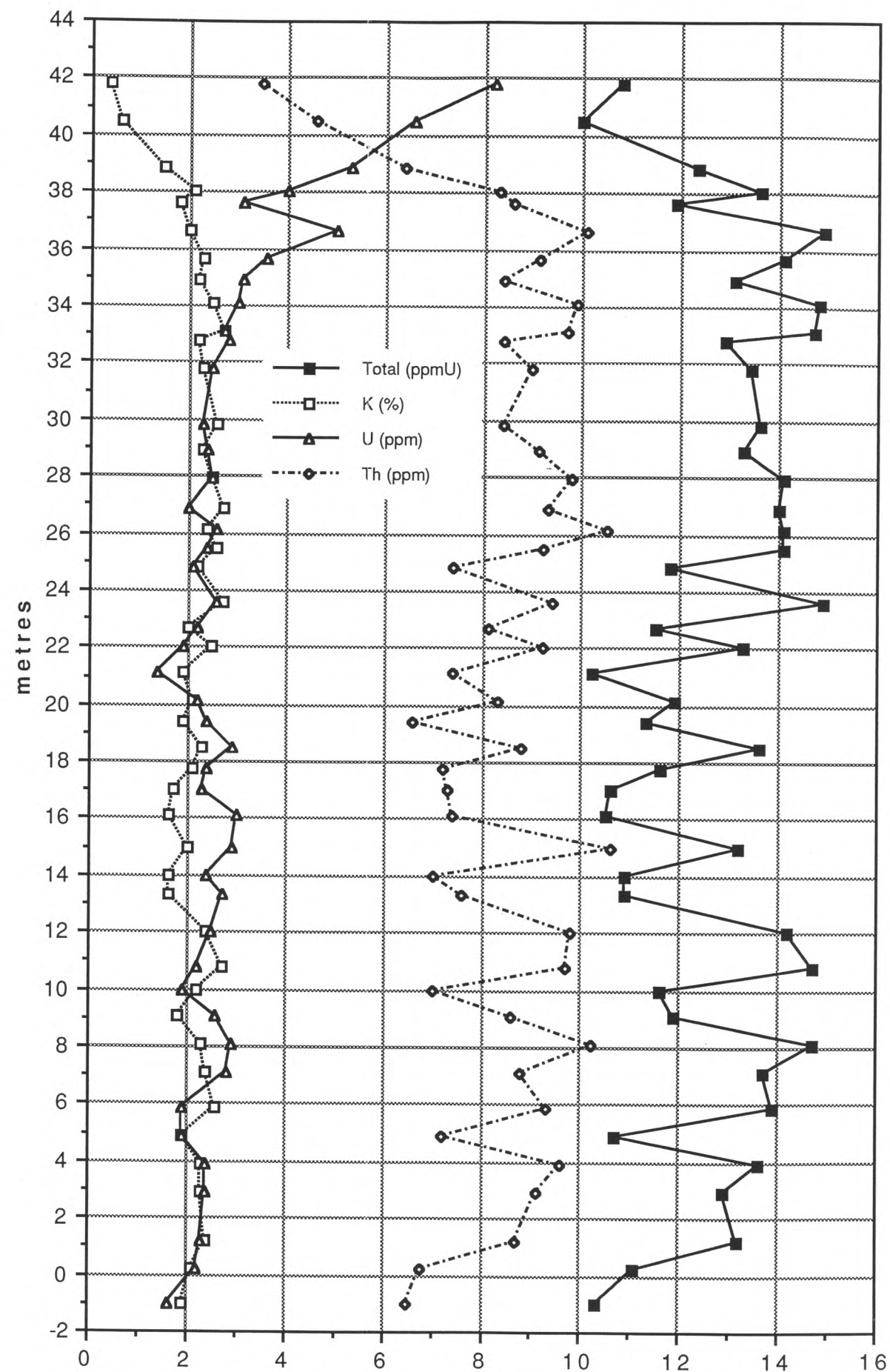
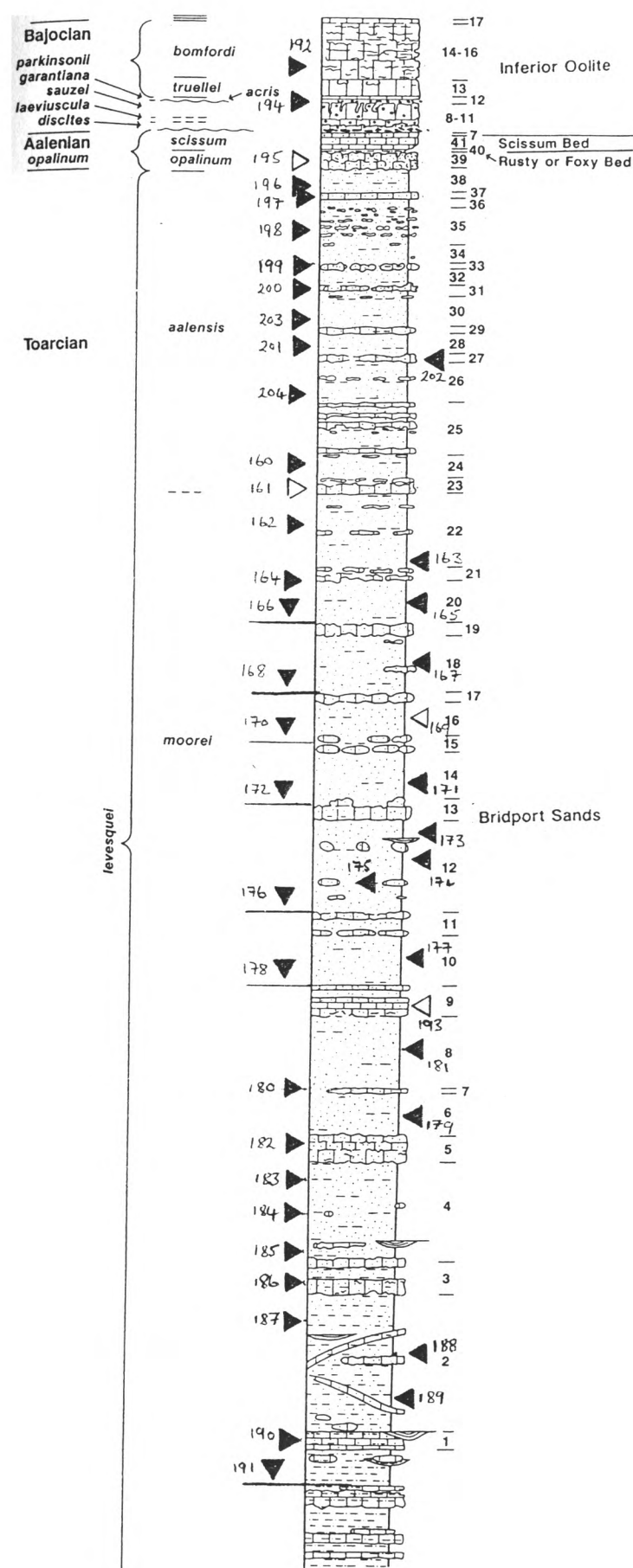


Figure 4.22 Bridport Sands spectral gamma-ray data. Stratigraphic log from Hesselbo & Jenkyns (in press); see Appendix 1 for symbols used to describe gamma-ray measurement stations and for tabulated data.

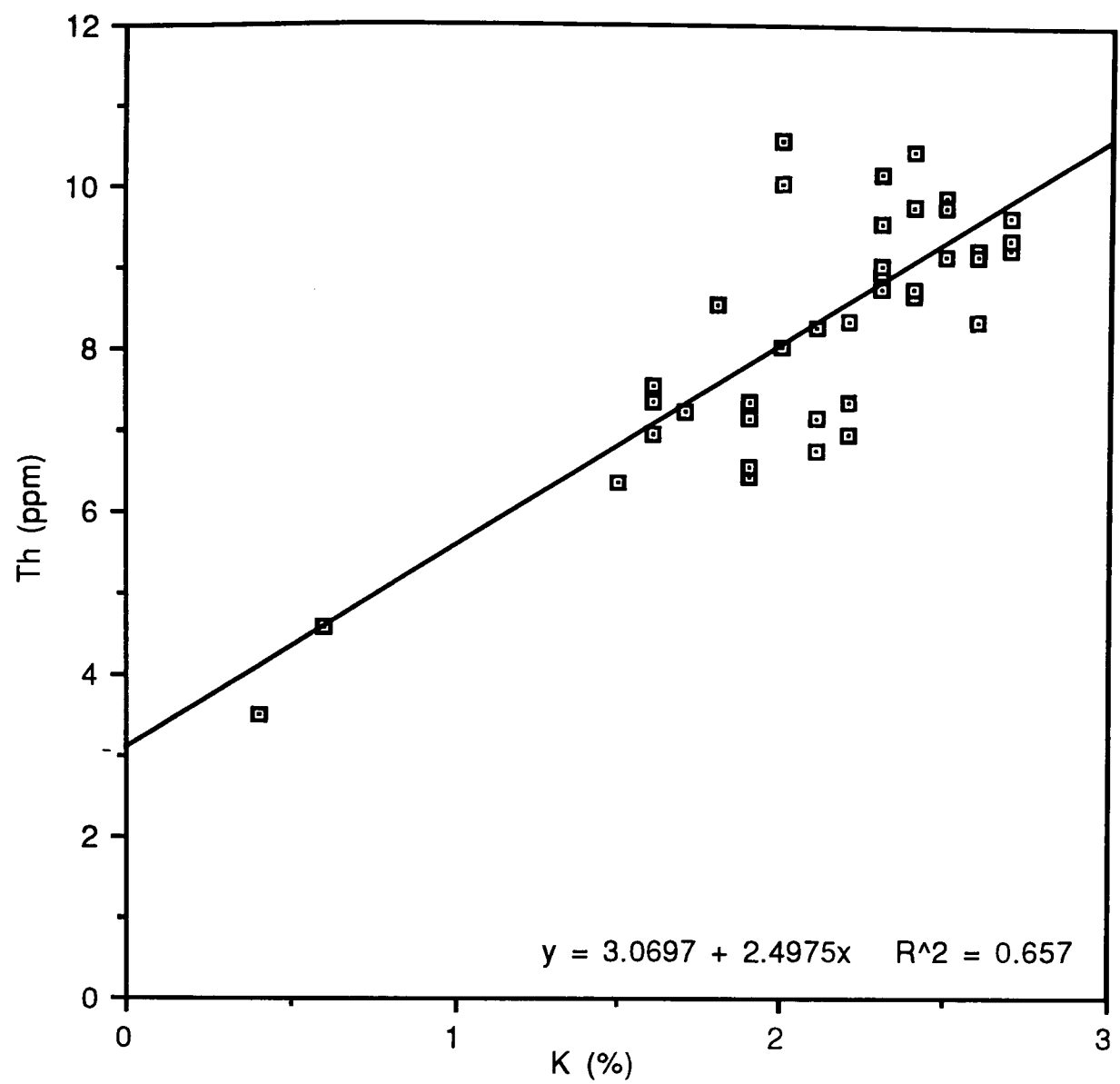


Figure 4.23a Thorium v. Potassium for the Bridport Sands

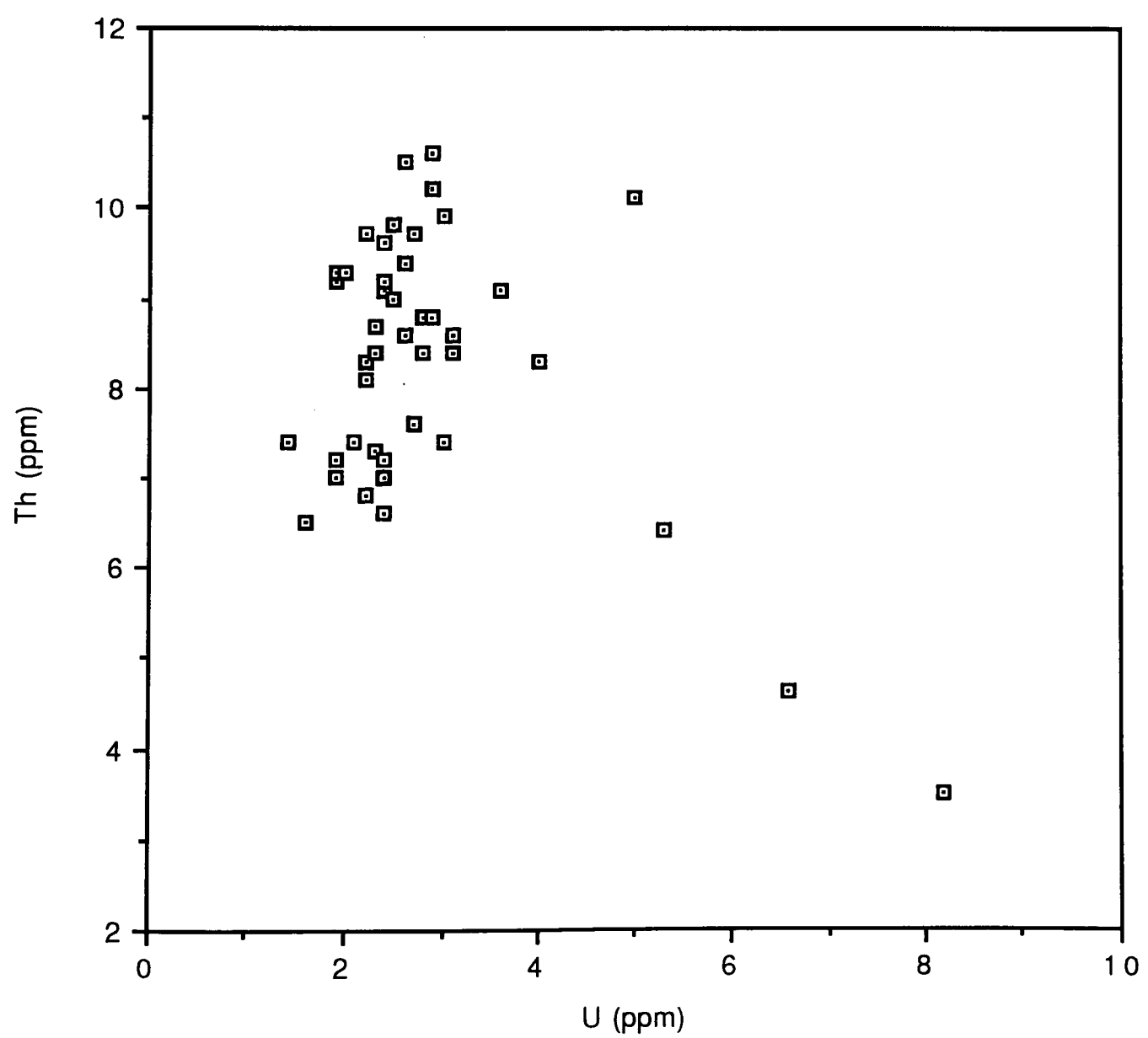


Figure 4.23b Thorium v. Uranium for the Bridport Sands

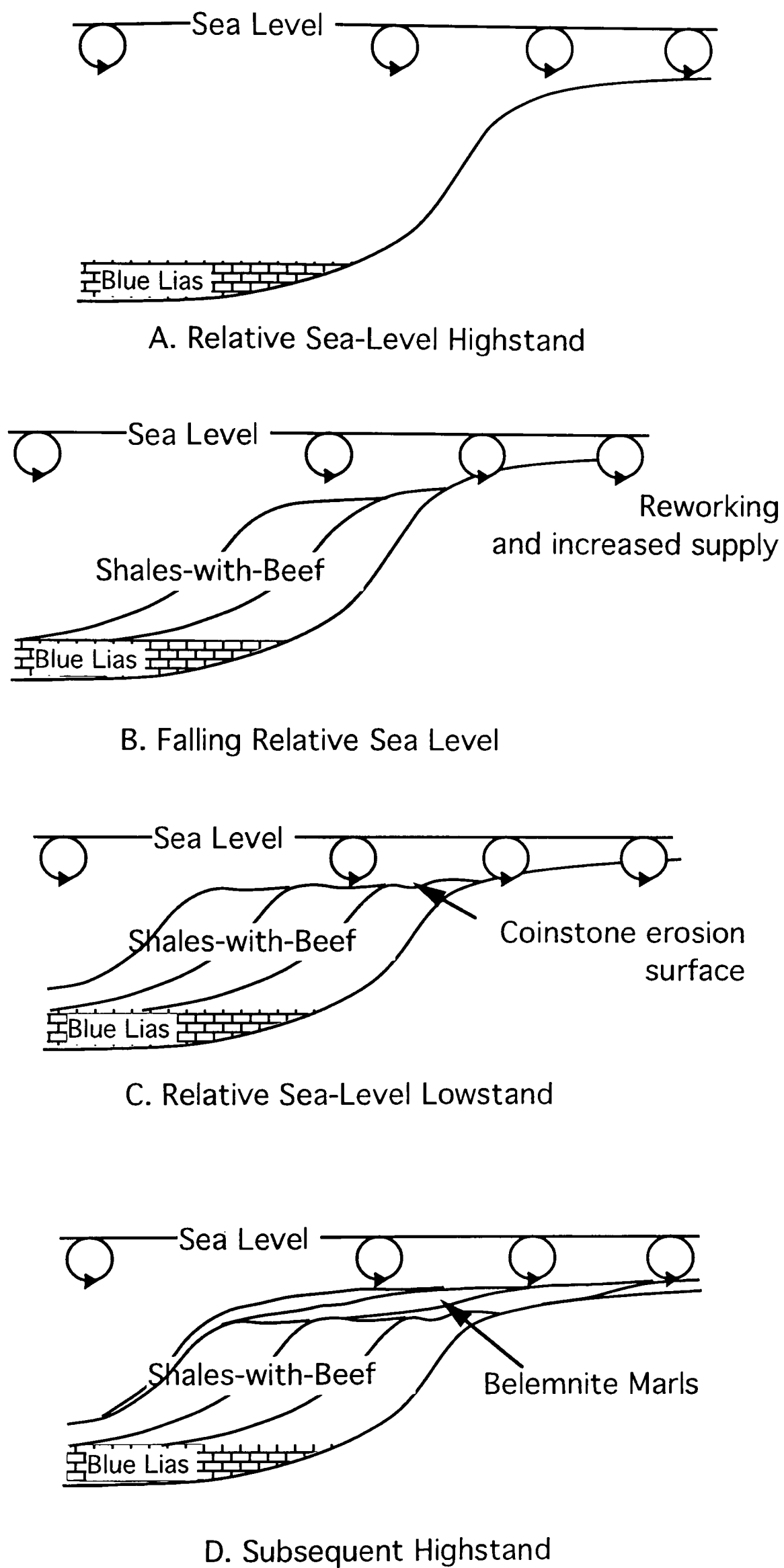


Figure 4.25 Model for the stratigraphic development of the Lower Lias of Dorset

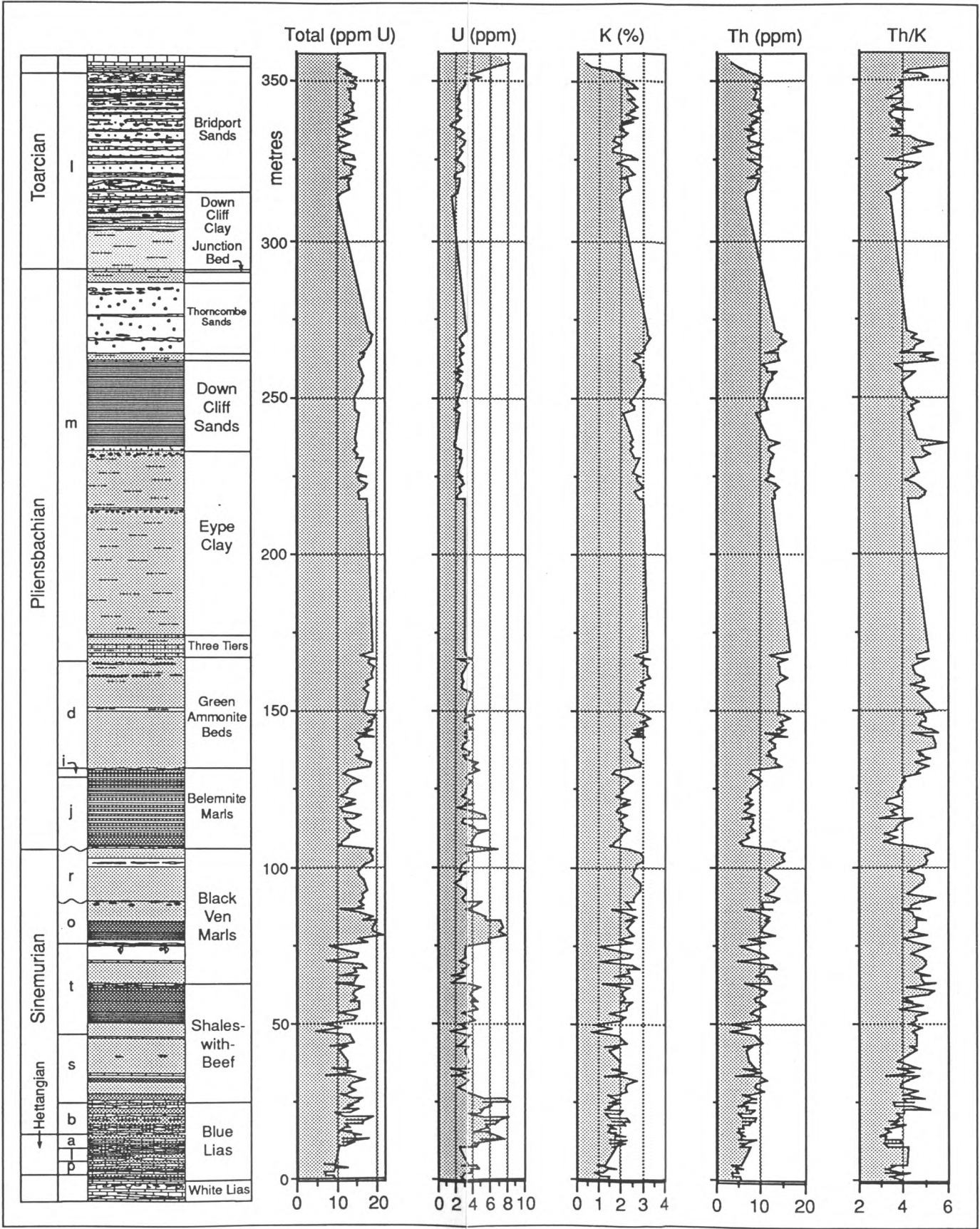


Figure 4.26 The Dorset Lower Jurassic: summary of stratigraphy (after Hesselbo & Jenkyns, in press) and spectral gamma-ray data. Ammonite Zones have been abbreviated to their initial letters for clarity.

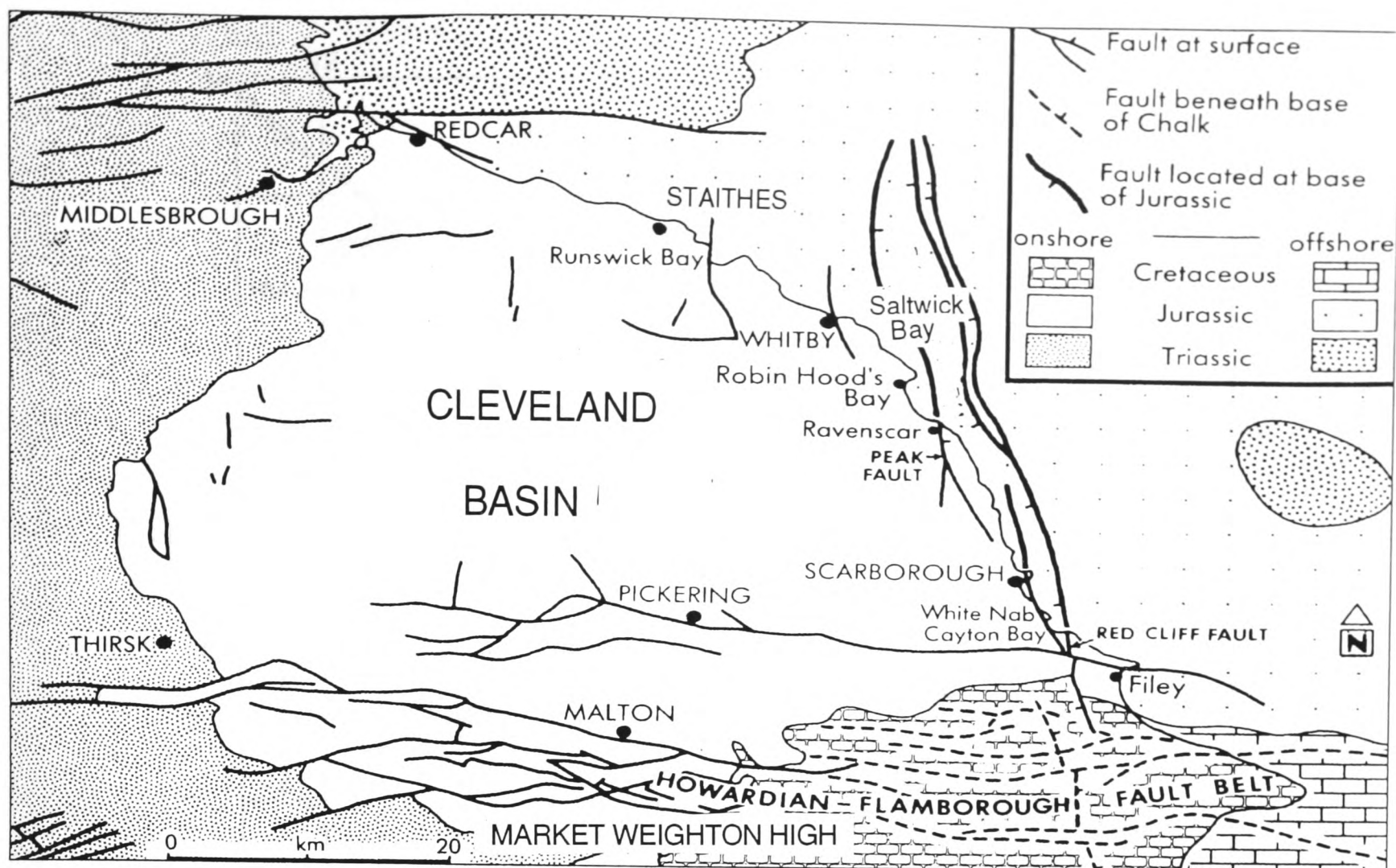


Figure 5.1a The Cleveland Basin (modified from Rawson & Wright, 1992)

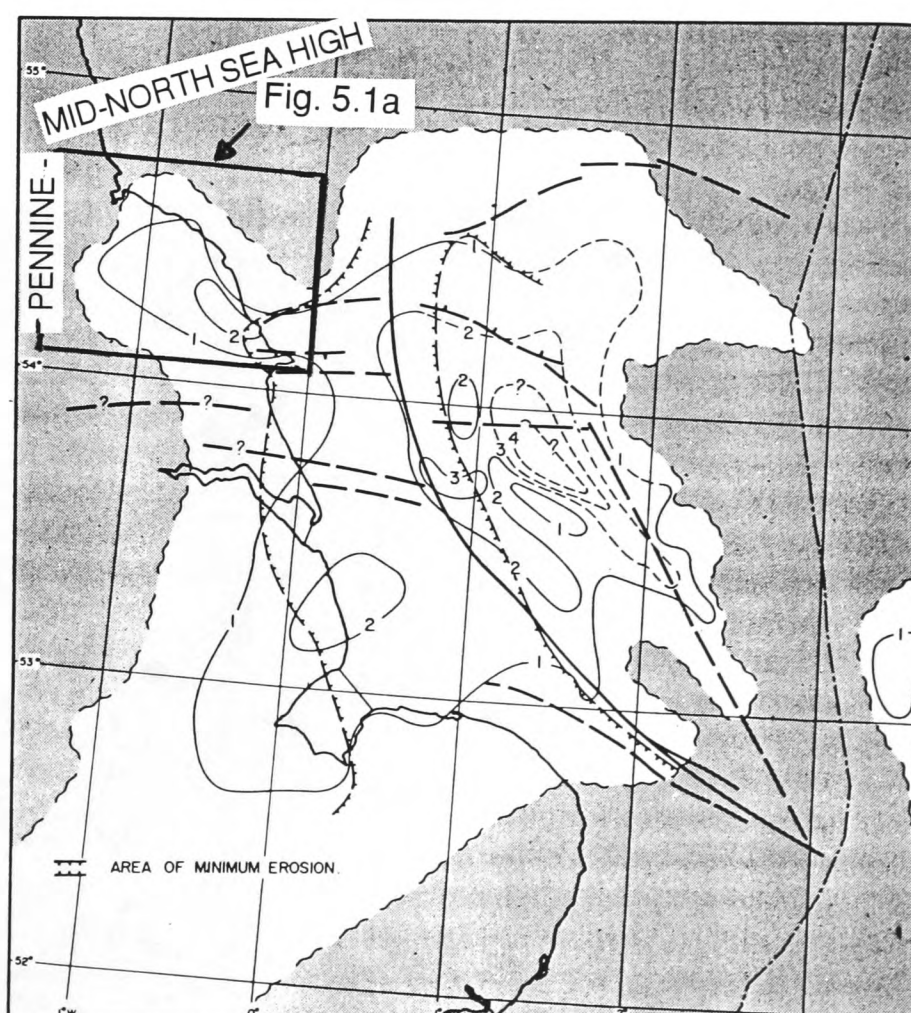


Figure 5.1b The Cleveland Basin in the context of the Southern North Sea Basin (Lias isopach in kilometres, from Glennie & Boegner, 1981)

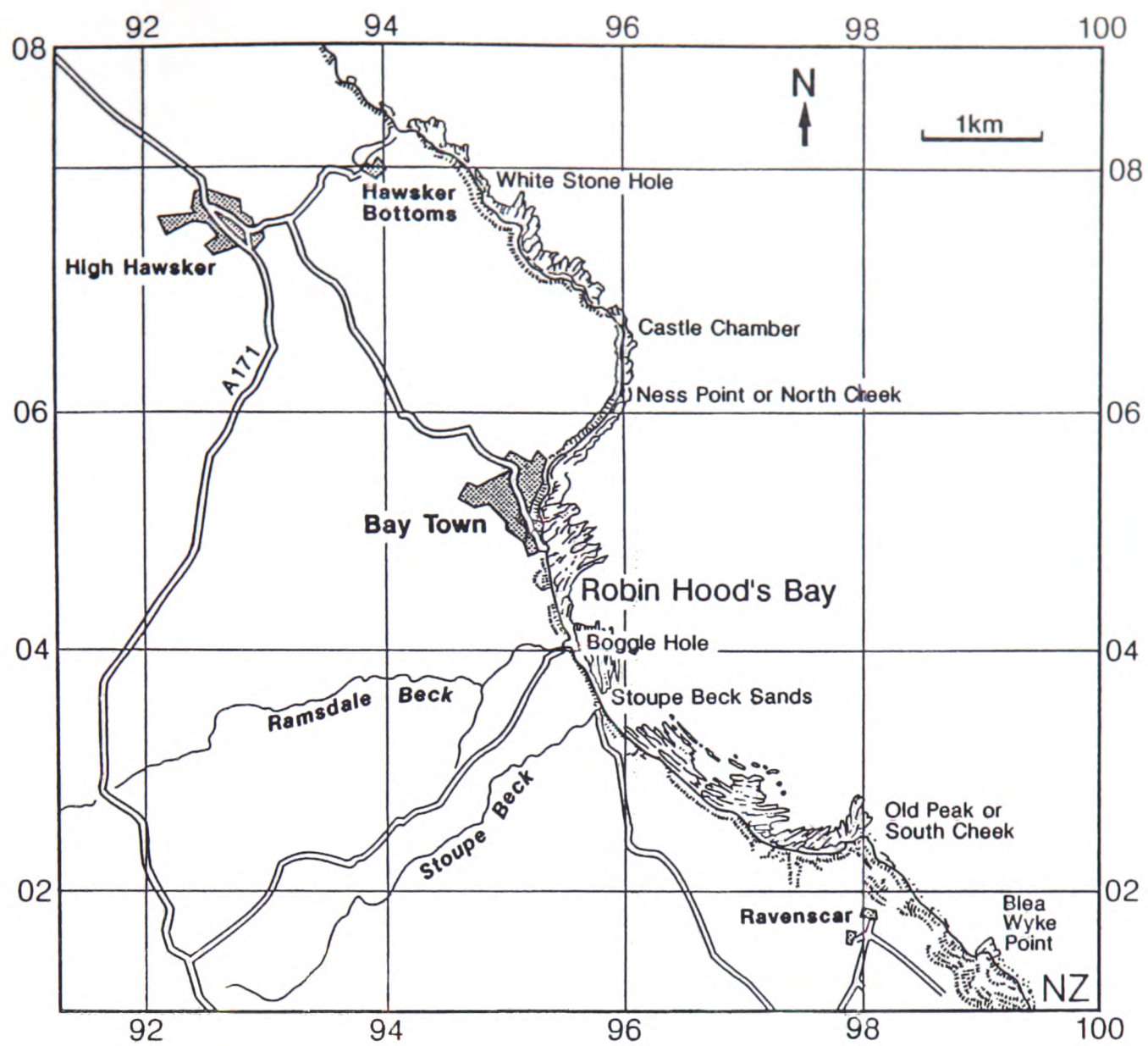


Figure 5.2a Detailed map showing locations of logged sections
(after Hesselbo & Jenkyns, in press)



Figure 5.2b Sand-filled scour within the Siliceous Shales, Robin Hood's Bay

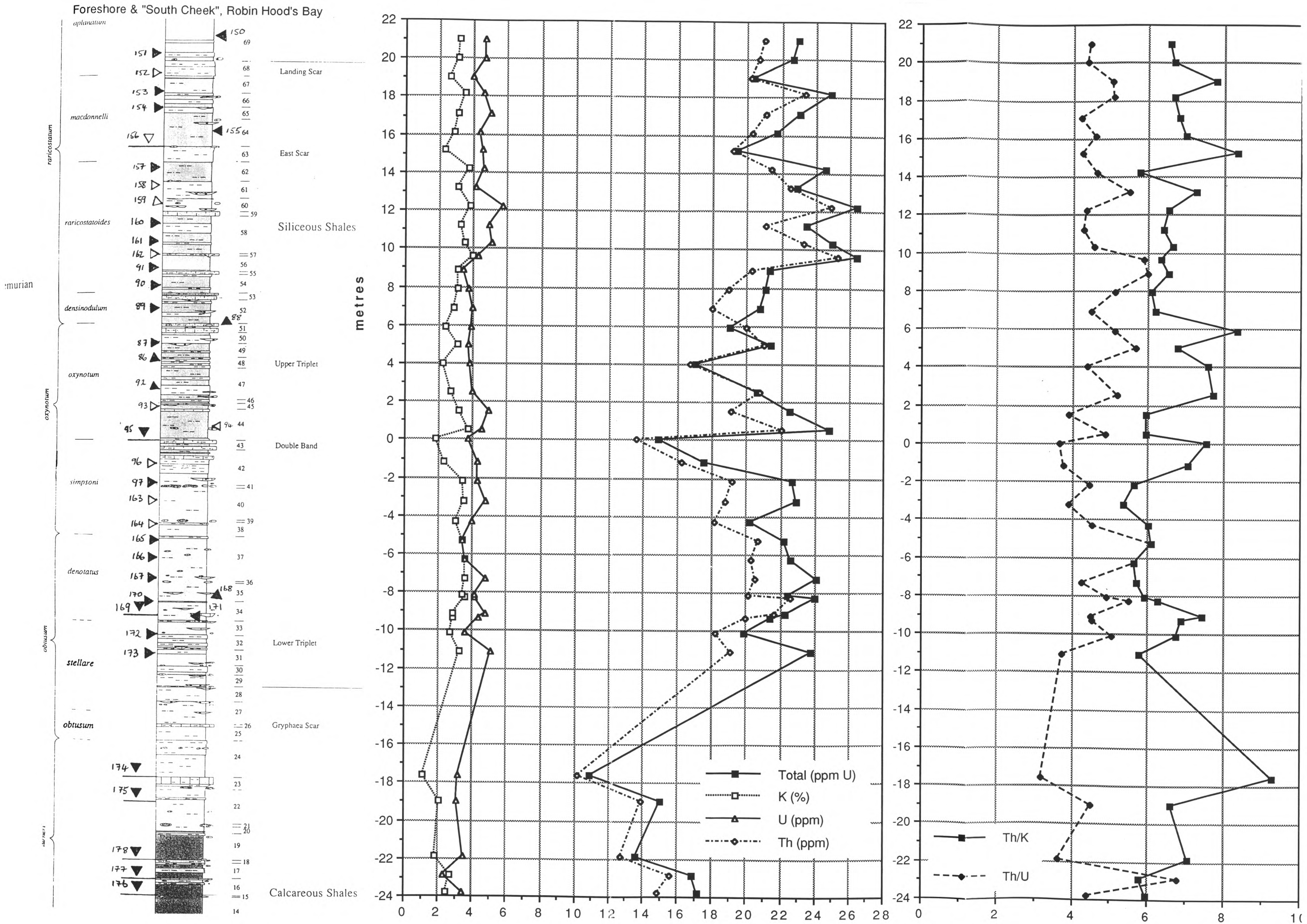


Figure 5.3 Calacreous Shales to Siliceous Shales spectral gamma-ray data. Stratigraphic log from Hesselbo & Jenkyns (in press): see Appendix 1 for symbols used to describe gamma-ray measurement stations and for tabulated data.

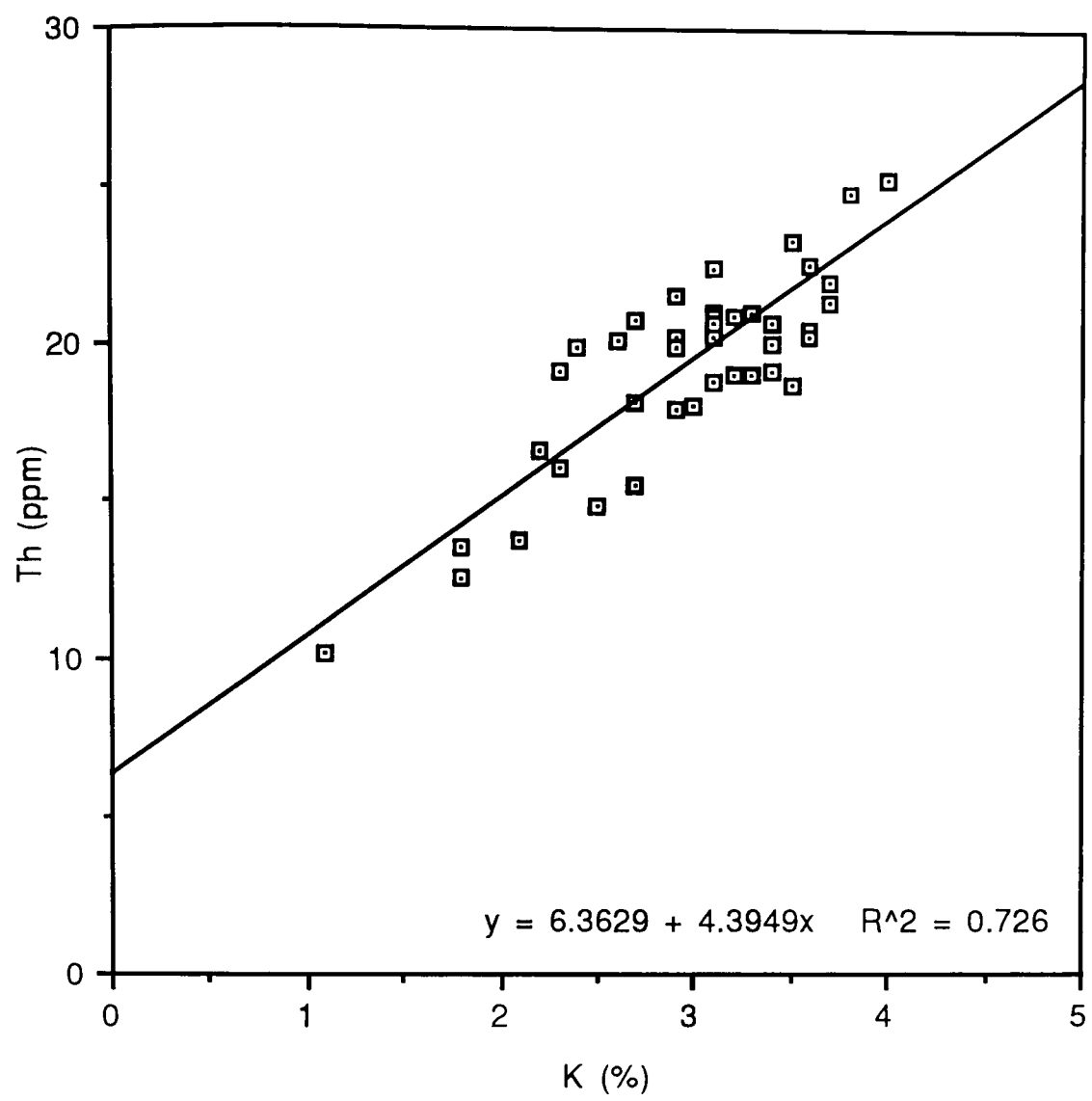


Figure 5.4a Th v. K for the Calcareous and Siliceous Shales

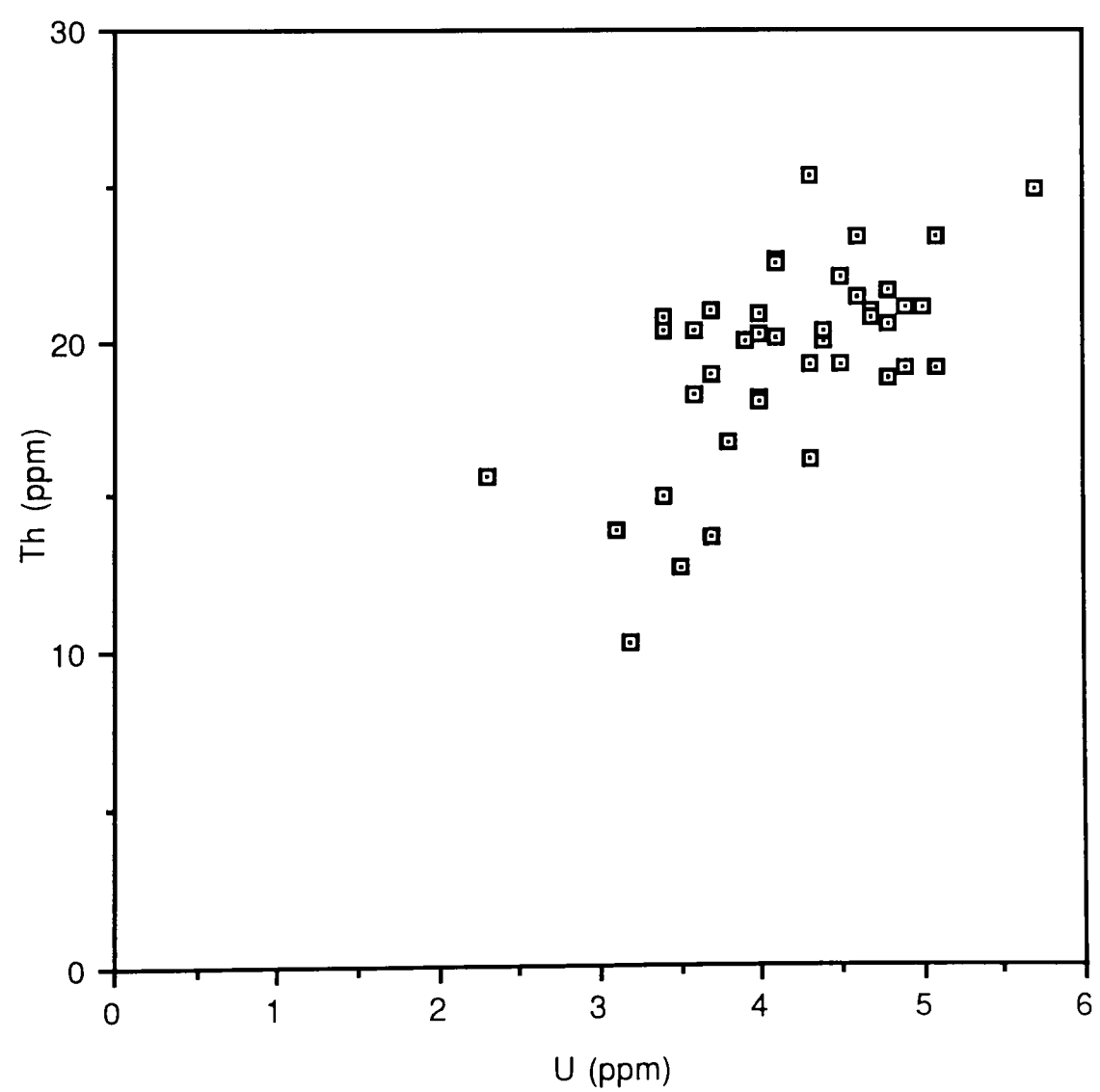


Figure 5.4b Th v. U for the Calcareous and Siliceous Shales



Figure 5.5a The Pyritous Shales, Robin Hood's Bay



Figure 5.5b Limestone-marl rhythms in the lower part of the Ironstone Shales, "North Cheek", Robin Hood's Bay

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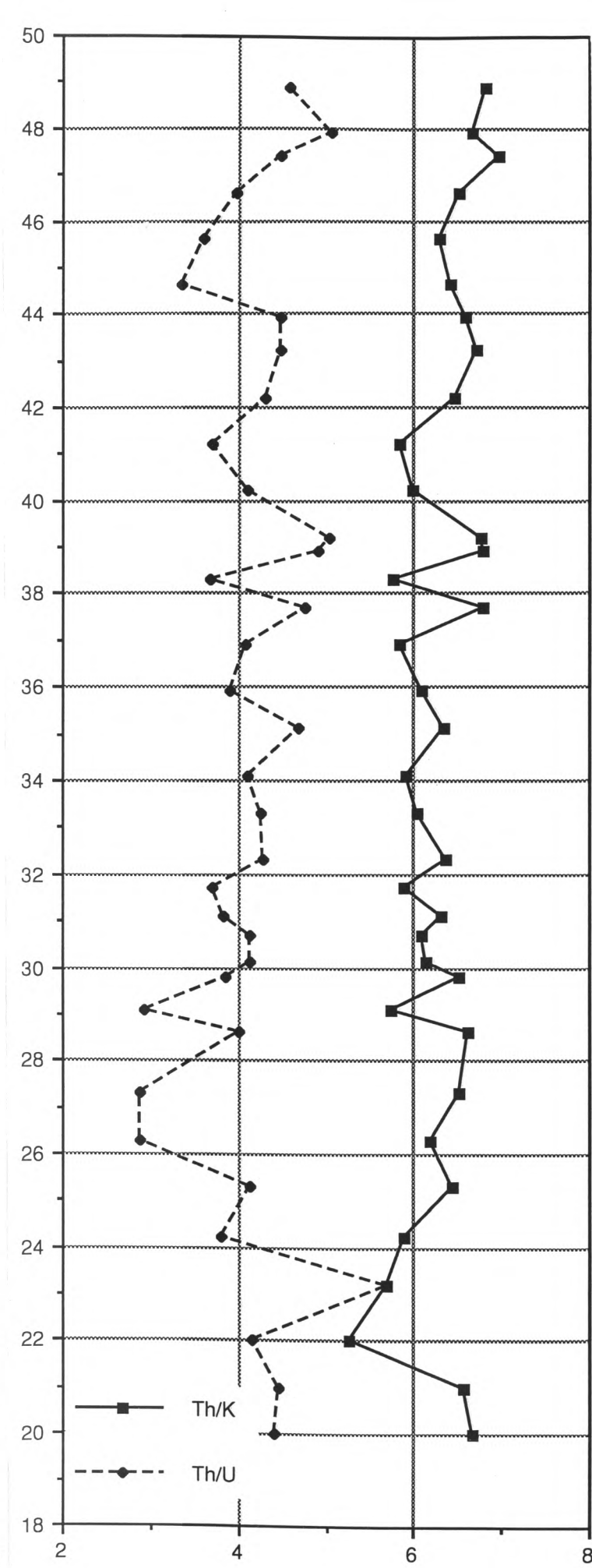
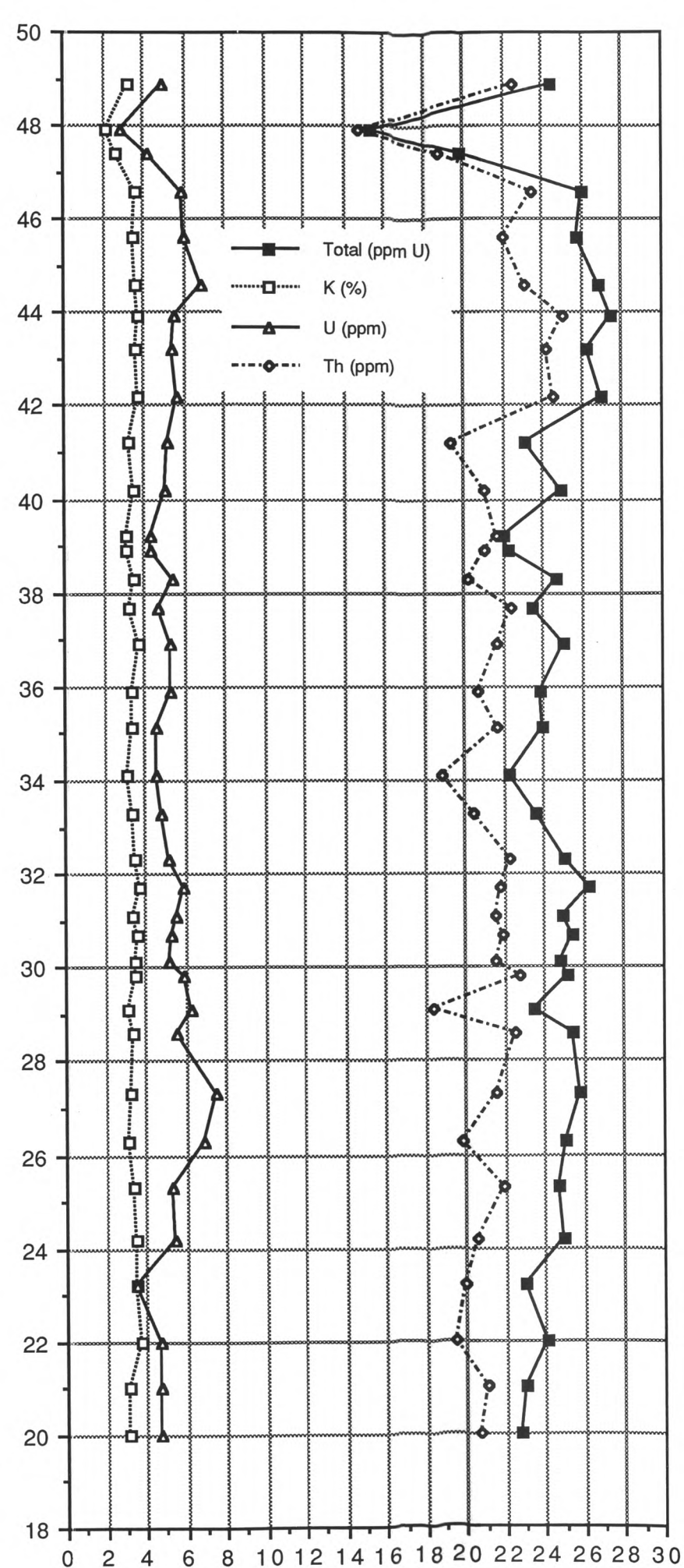
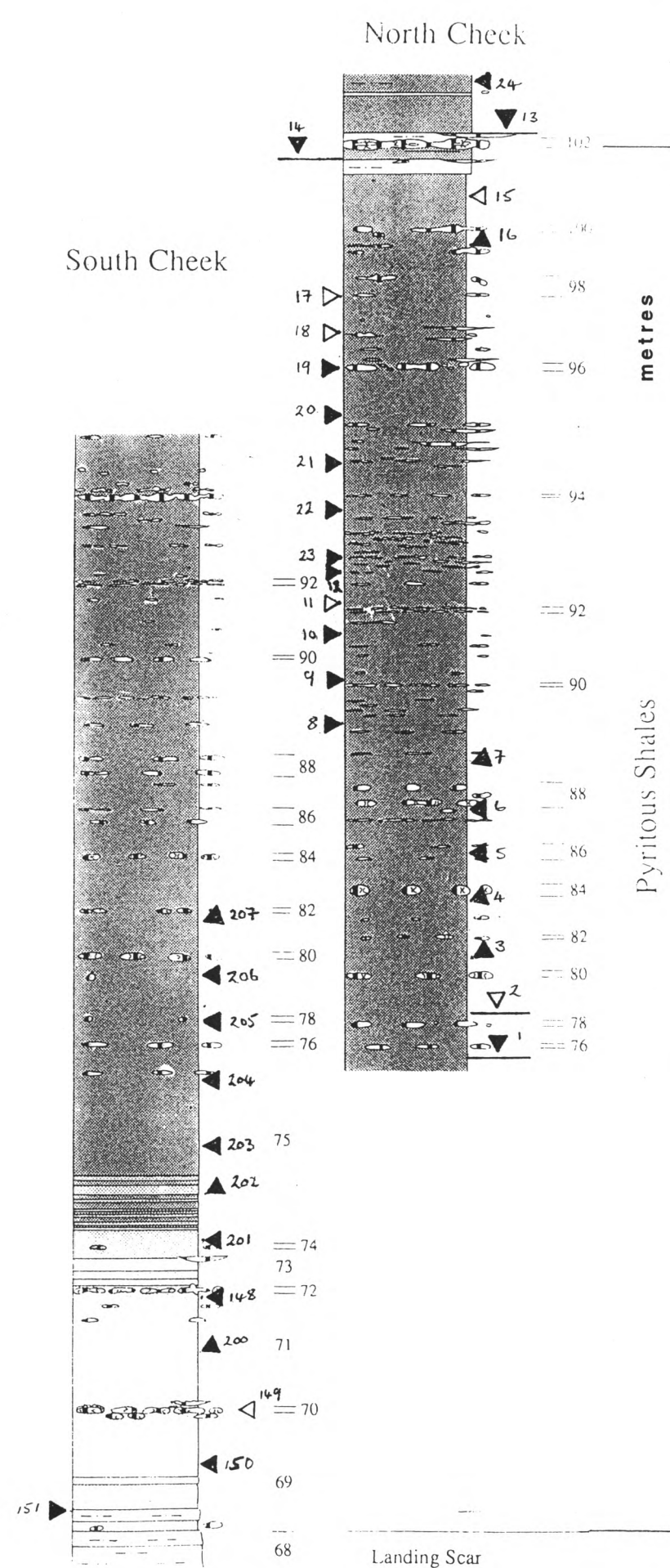


Figure 5.6 Pyritous Shales spectral gamma-ray data. Stratigraphic log from Hesselbo & Jenkyns (in press); see Appendix 1 for symbols used to describe gamma-ray measurement stations and for tabulated data.

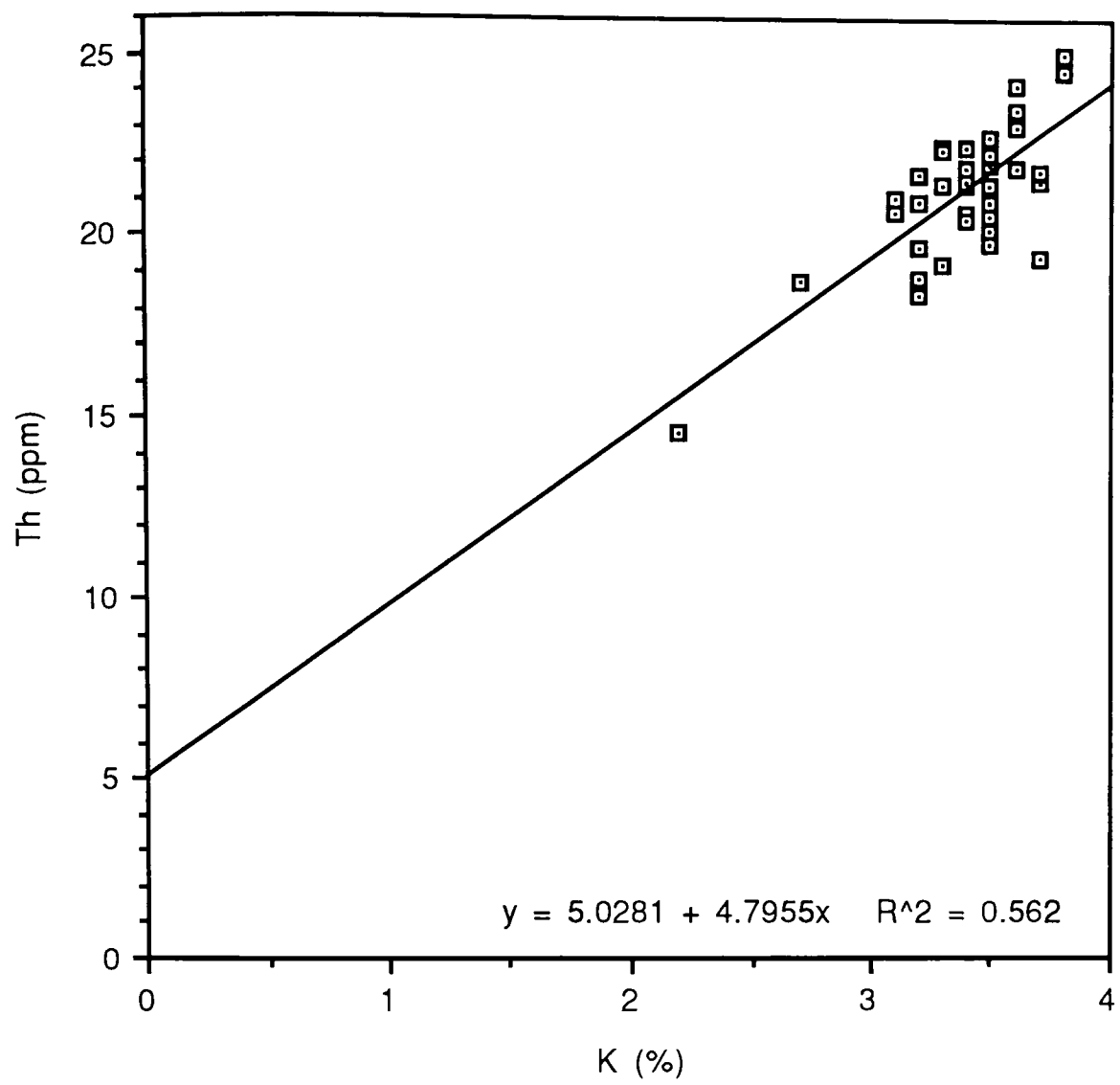


Figure 5.7a Th v. K. for the Pyritous Shales

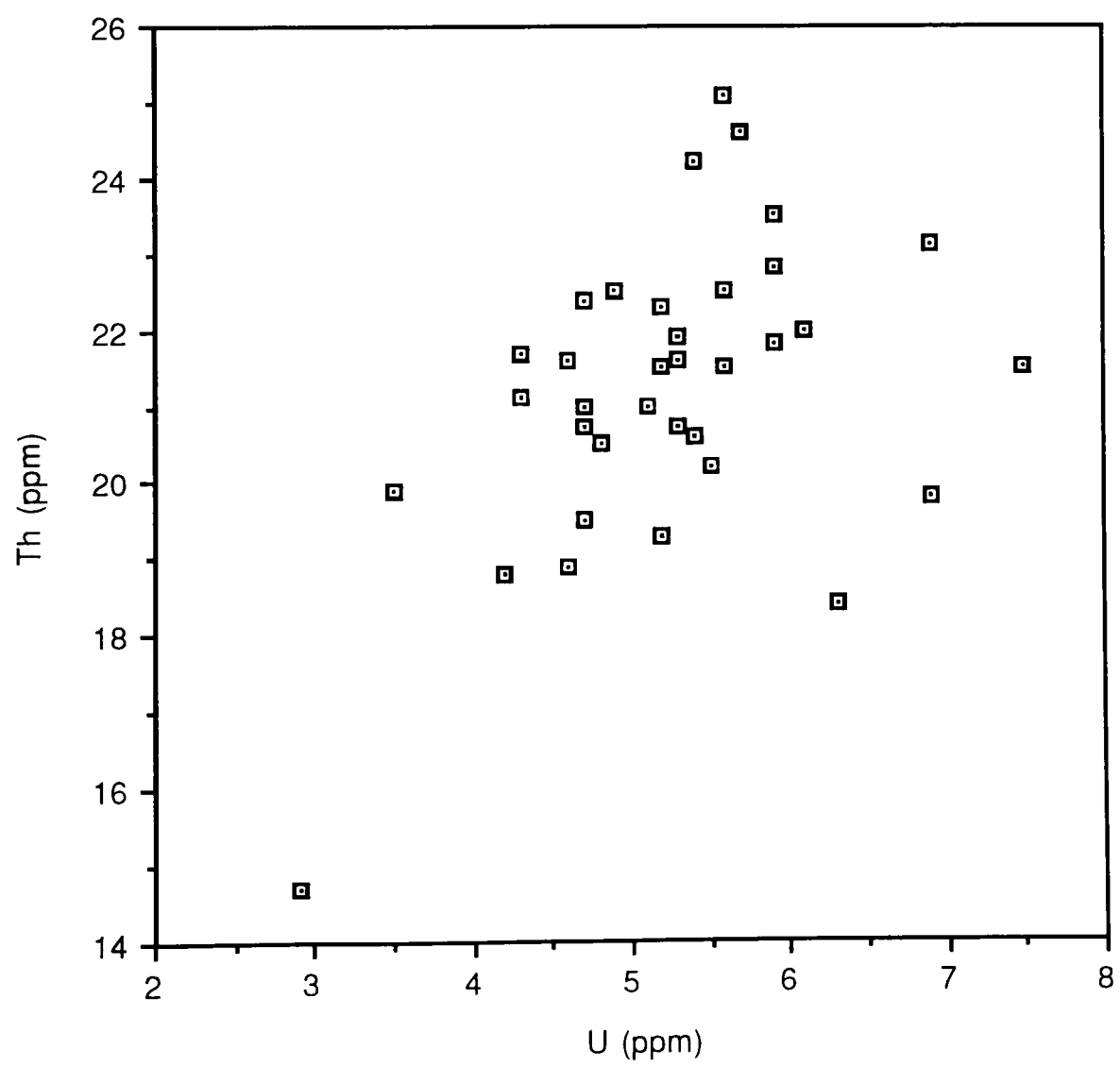


Figure 5.7b Th v. U for the Pyritous Shales

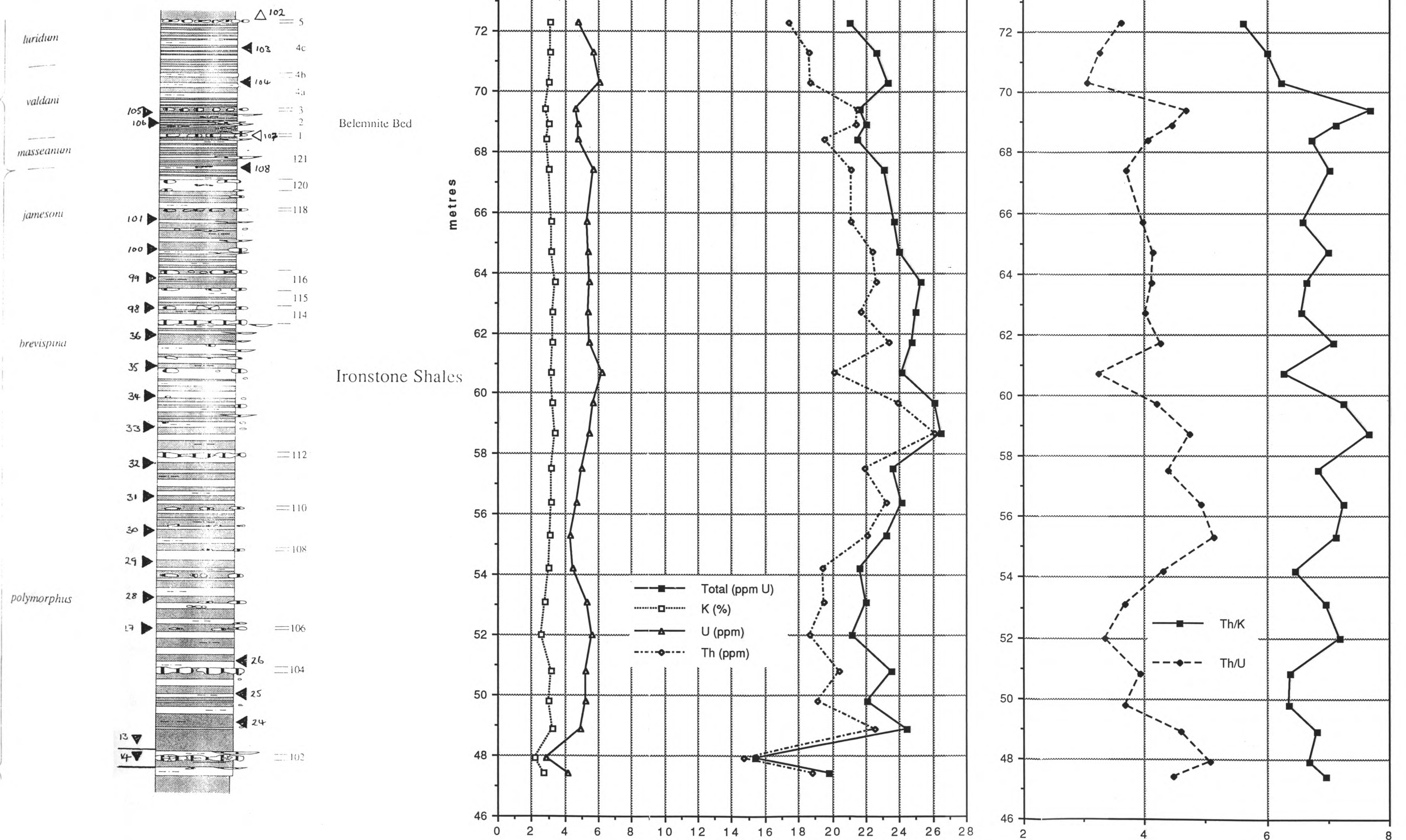


Figure 5.8 Spectral gamma-ray data from the lower (limestone-marl) part of the Ironstone Shales. Stratigraphic log from Hesselbo & Jenkyns (in press); see Appendix 1 for symbols used to describe gamma-ray measurement stations and for tabulated data.

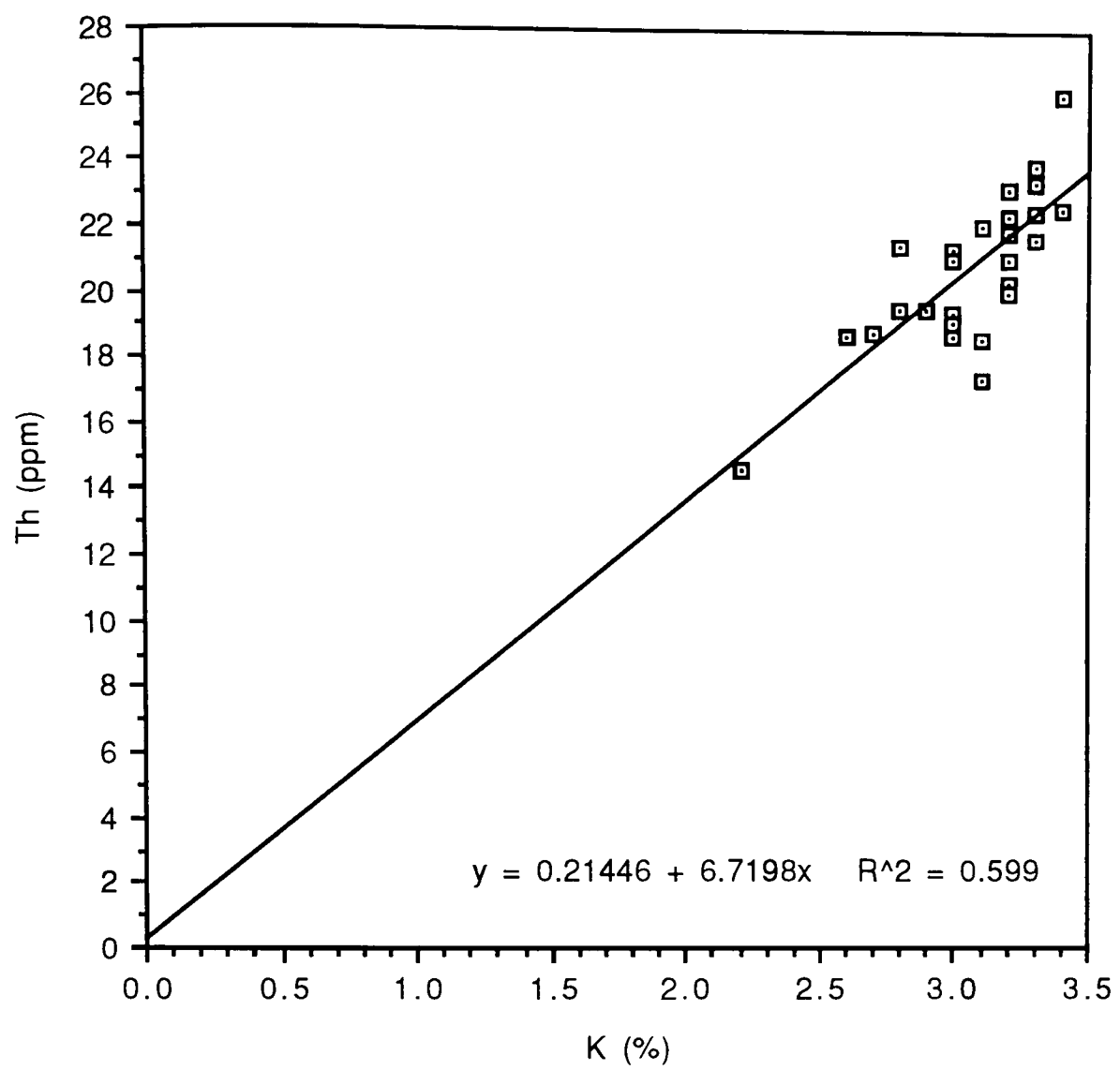


Figure 5.9a Th v. K for the Ironstone Shales (lower part)

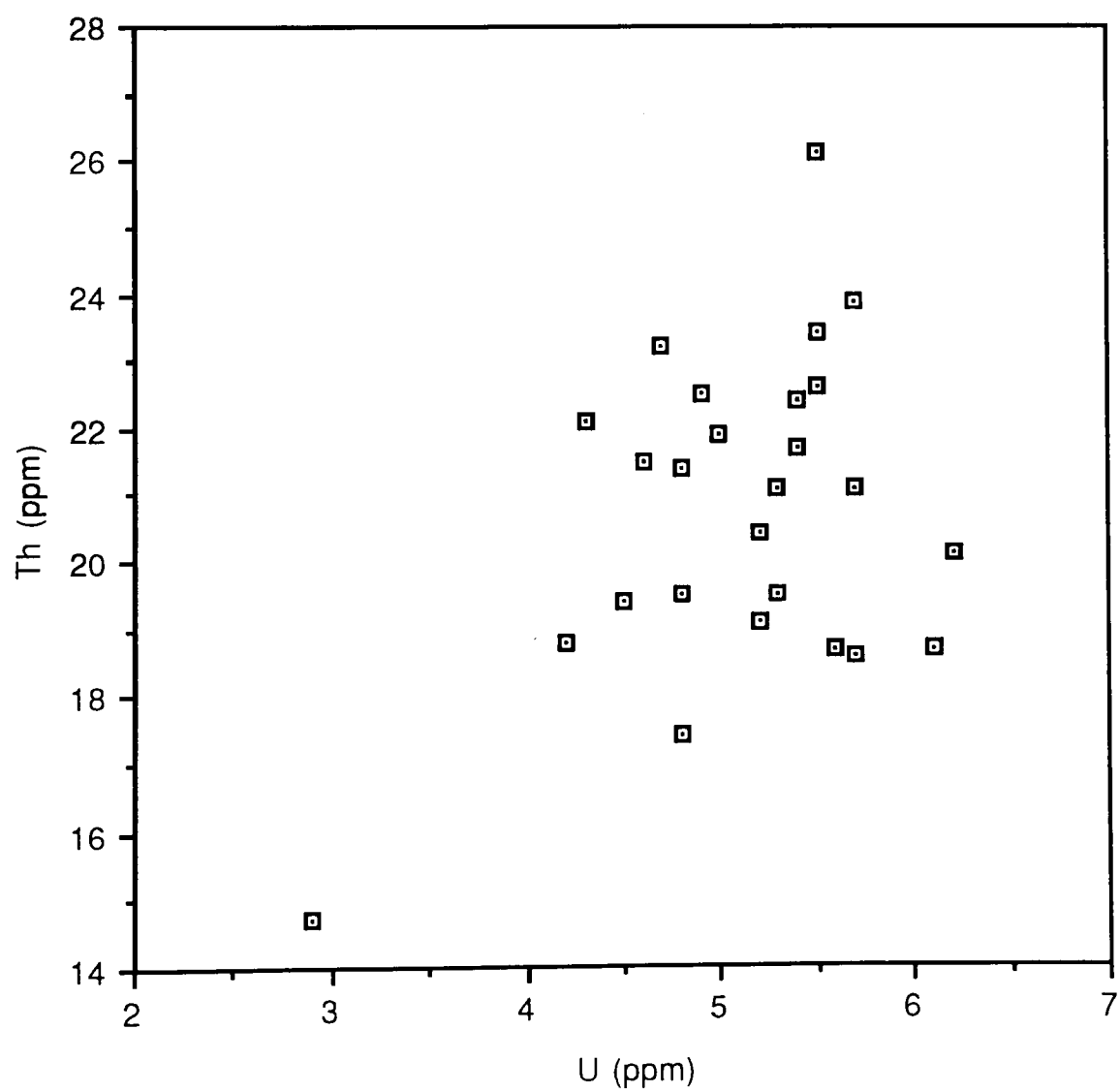


Figure 5.9b Th v. U for the Ironstone Shales (lower part)

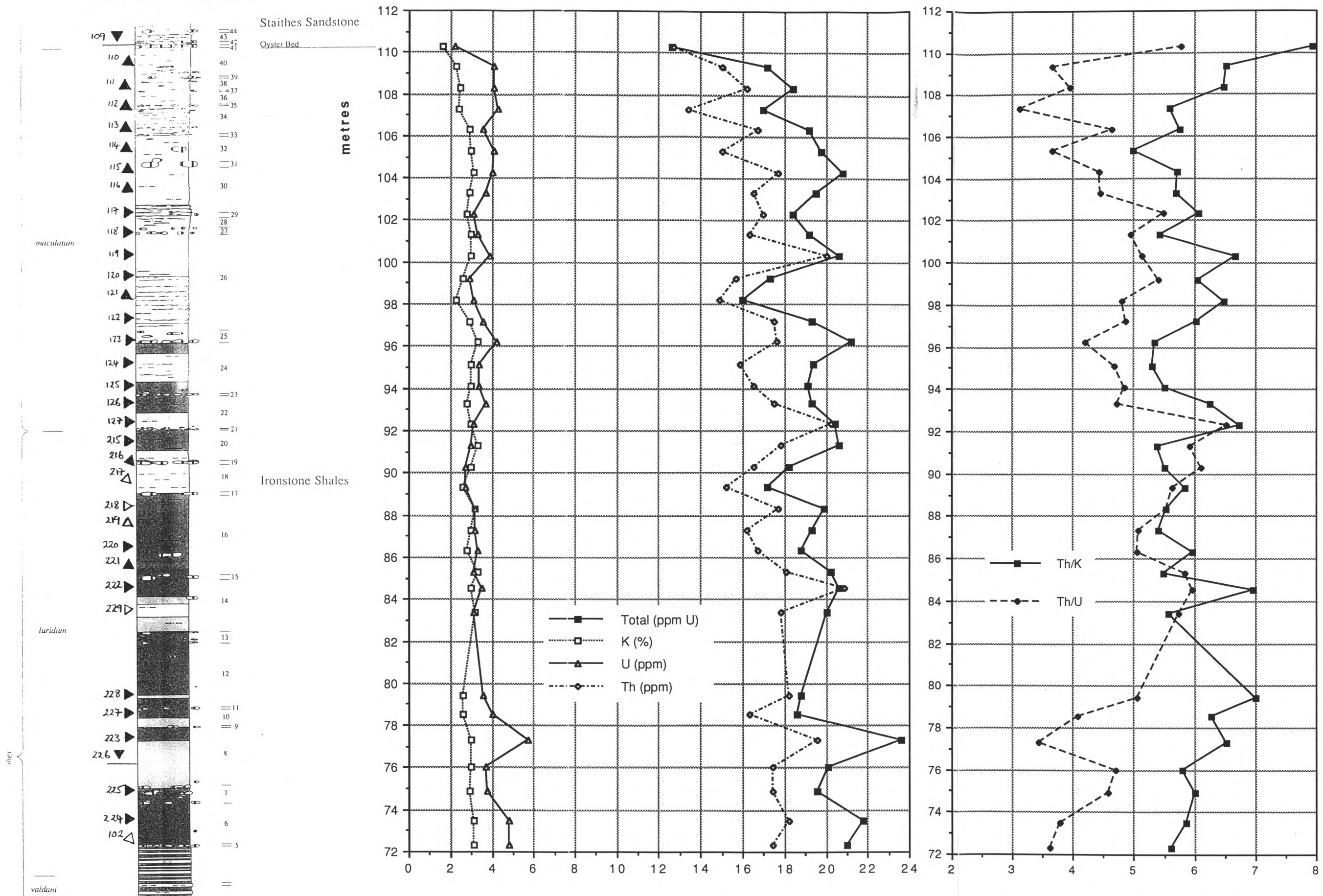


Figure 5.10 Spectral gamma-ray data from the upper (monotonous) part of the Ironstone Shales. Stratigraphic log from Hesselbo & Jenkyns (in press); see Appendix 1 for symbols used to describe gamma-ray measurement stations and for tabulated data.

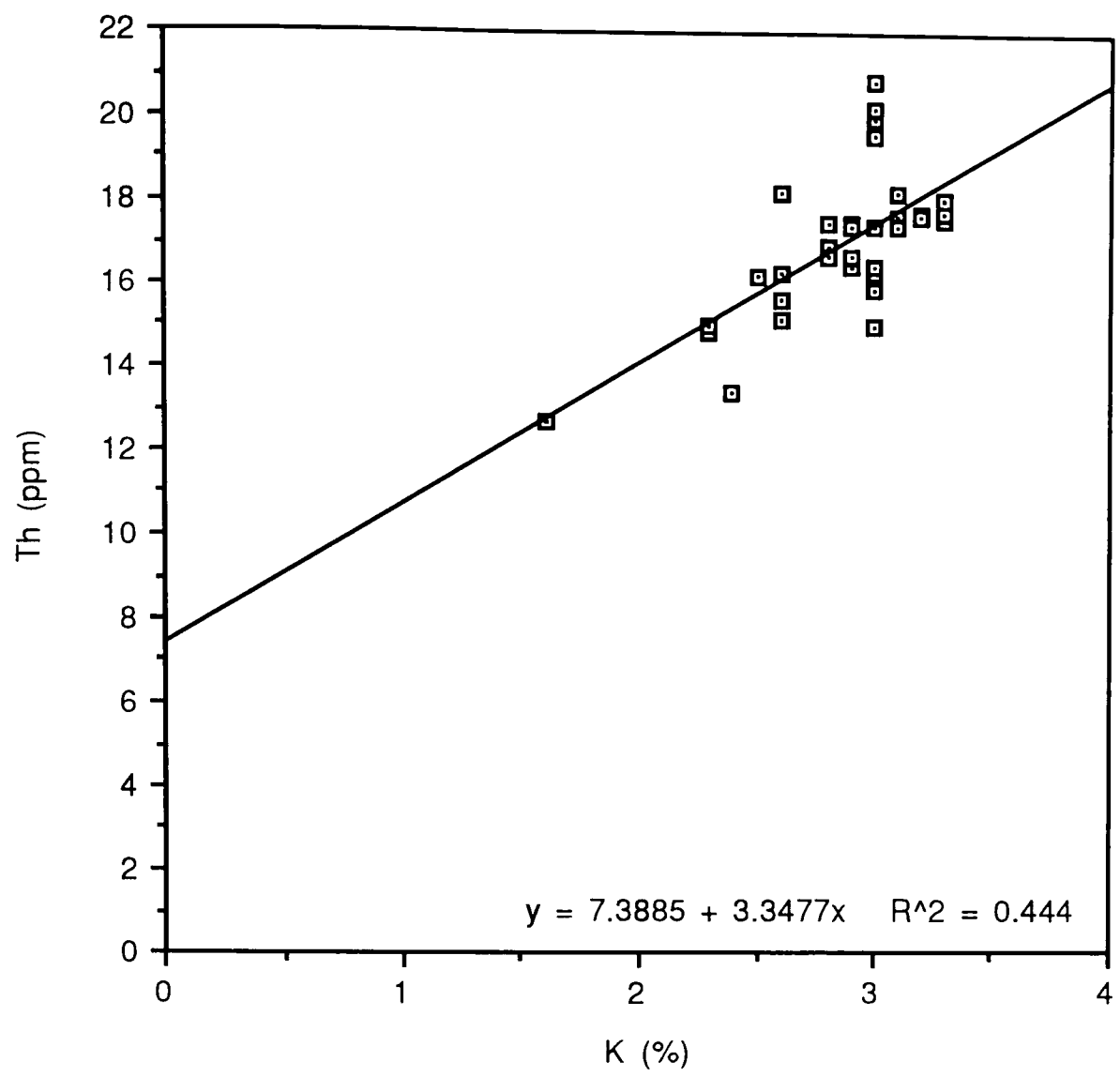


Figure 5.11a Th v. K for the Ironstone Shales (upper part)

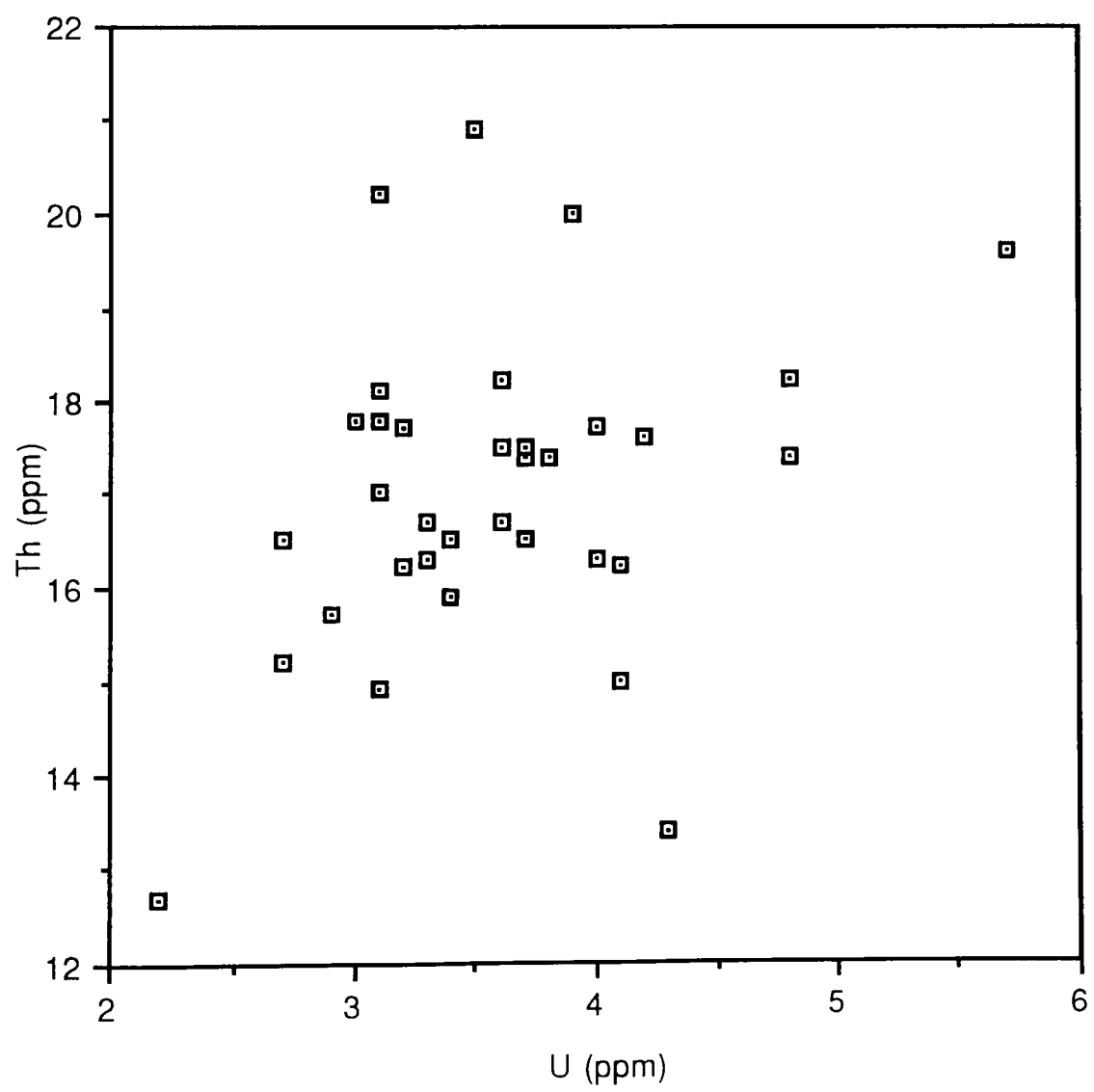


Figure 5.11b Th v. U for the Ironstone Shales (upper part)



Figure 5.12a General view of the Staithes Sandstone, Castle Chamber, north of Robin Hood's Bay. Bedsets 59-60 and 6 are marked (see fig. 5.13)

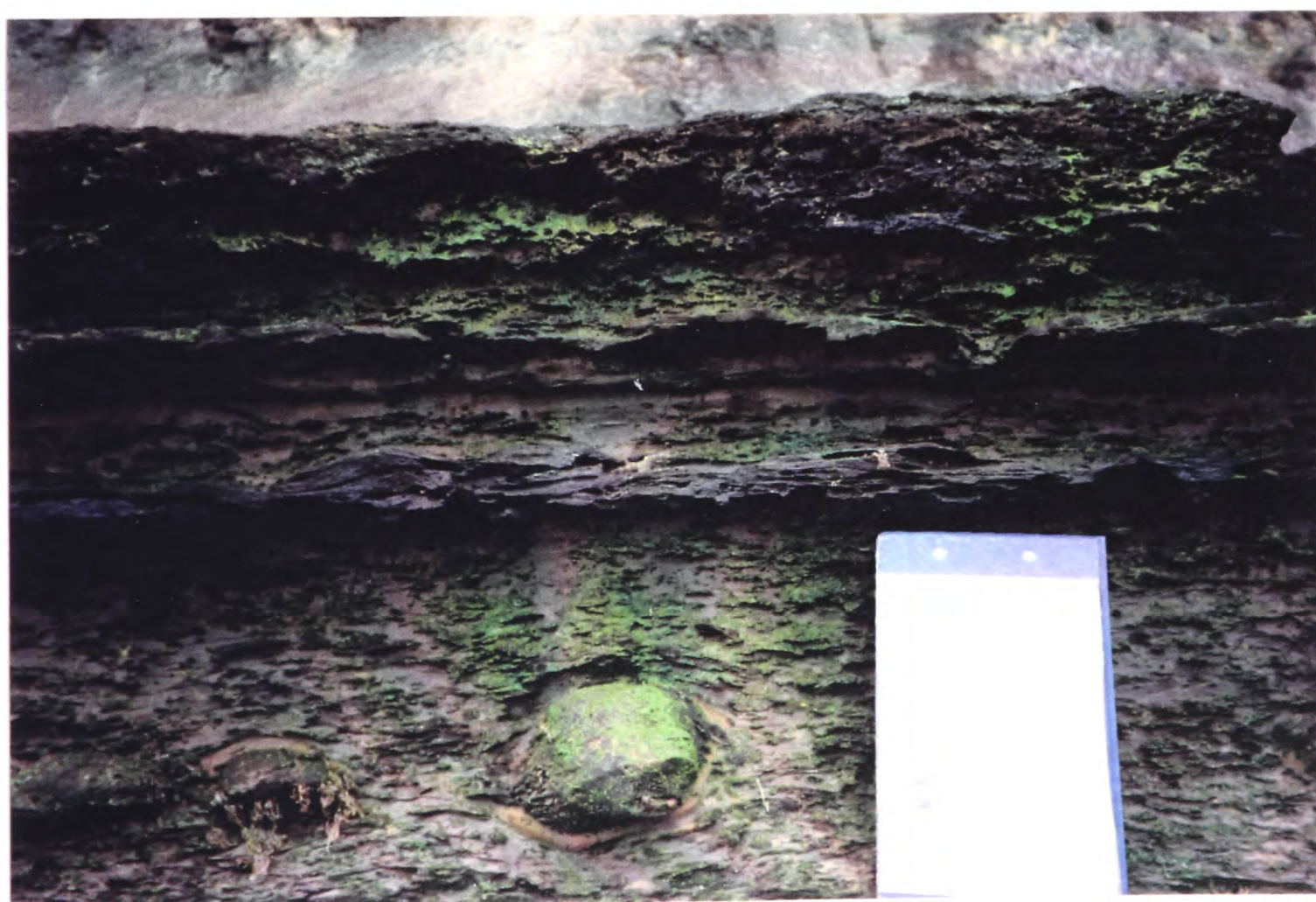


Figure 5.12b Detail of Bedset 6, Staithes Sandstone

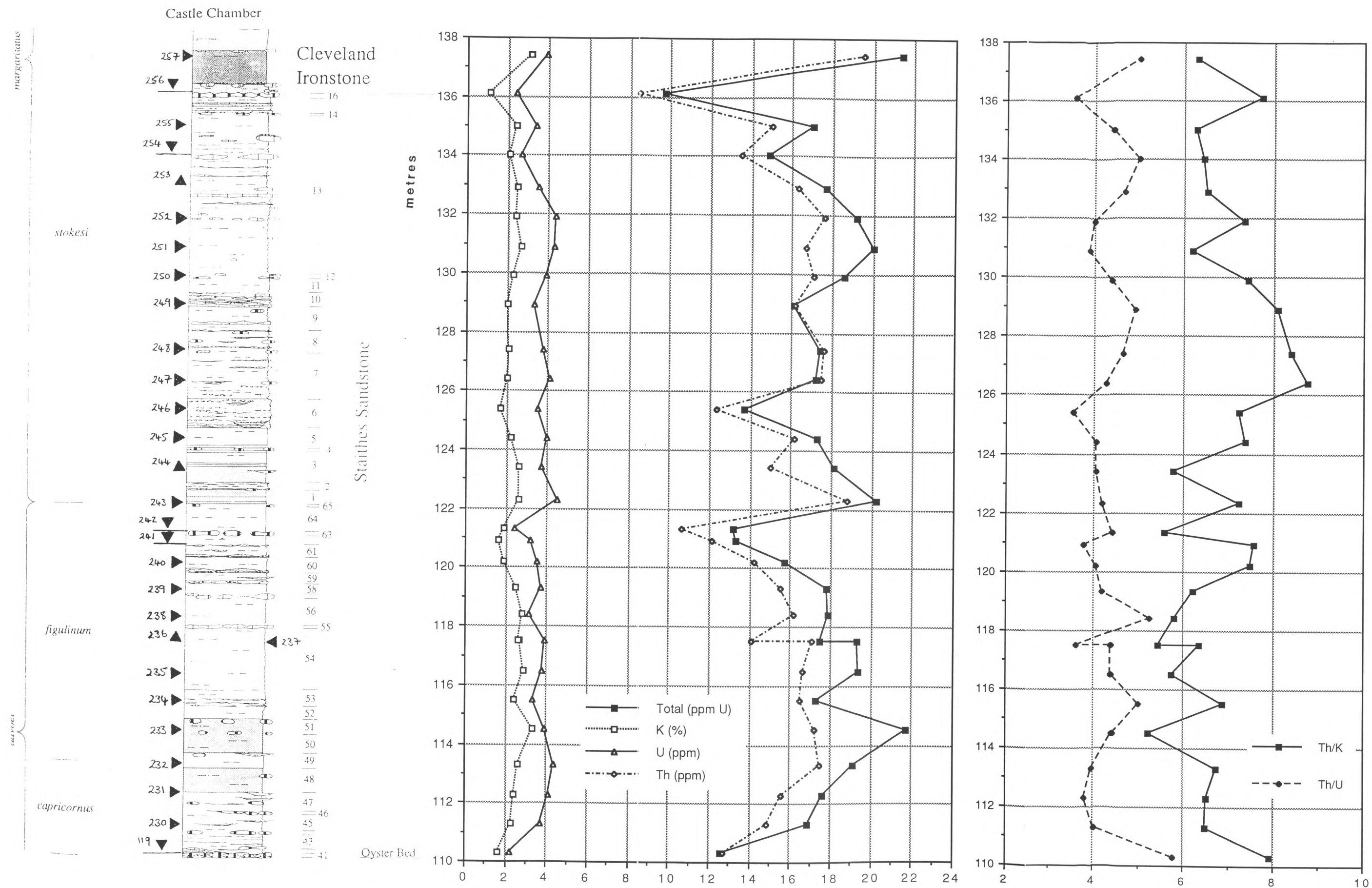


Figure 5.13 Staithe Sandstone spectral gamma-ray data. Stratigraphic log from Hesselbo & Jenkyns (in press); see Appendix 1 for symbols used to describe gamma-ray measurement stations and for tabulated data.

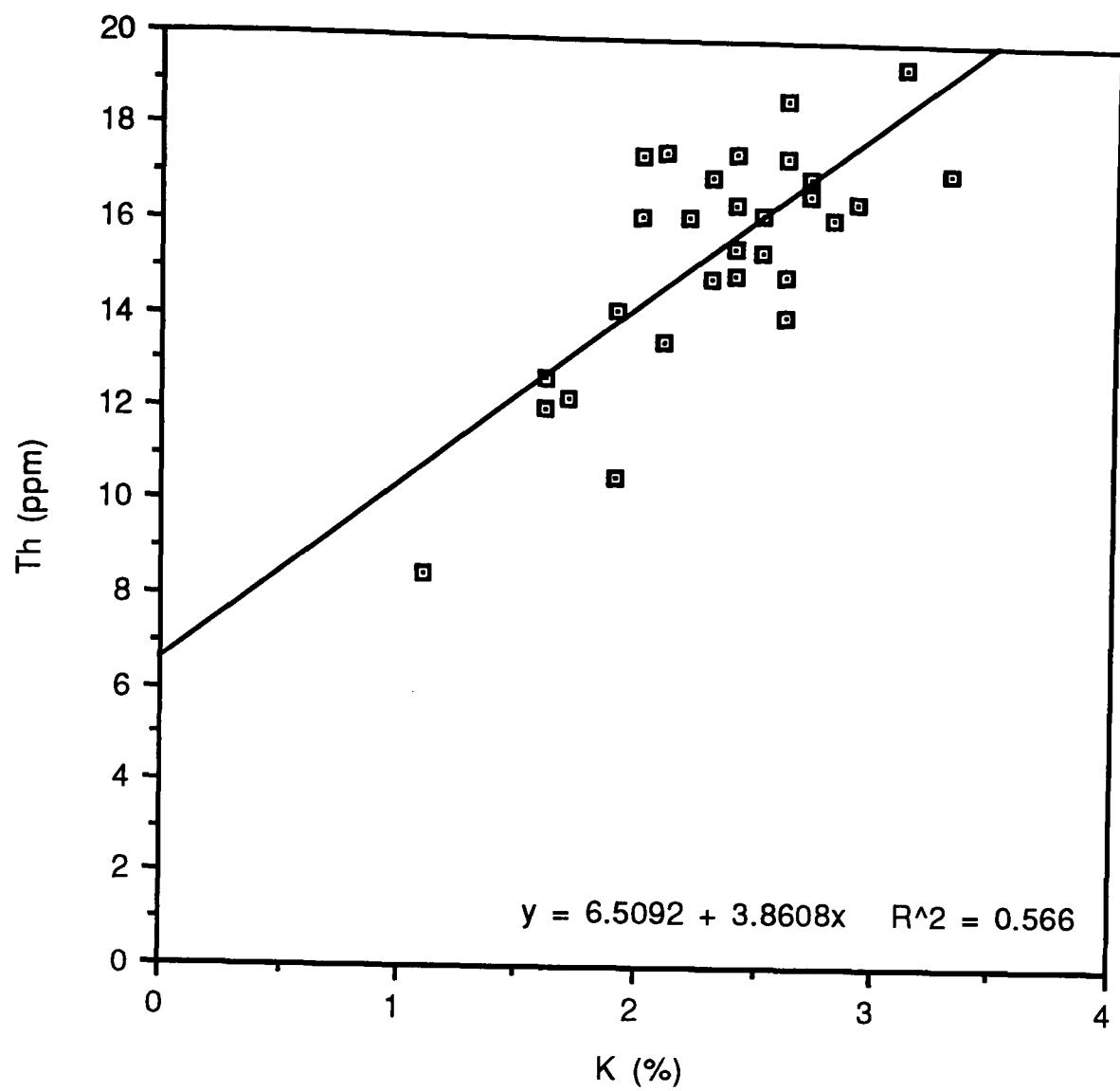


Figure 5.14a Th v. K for the Staithes Sandstone

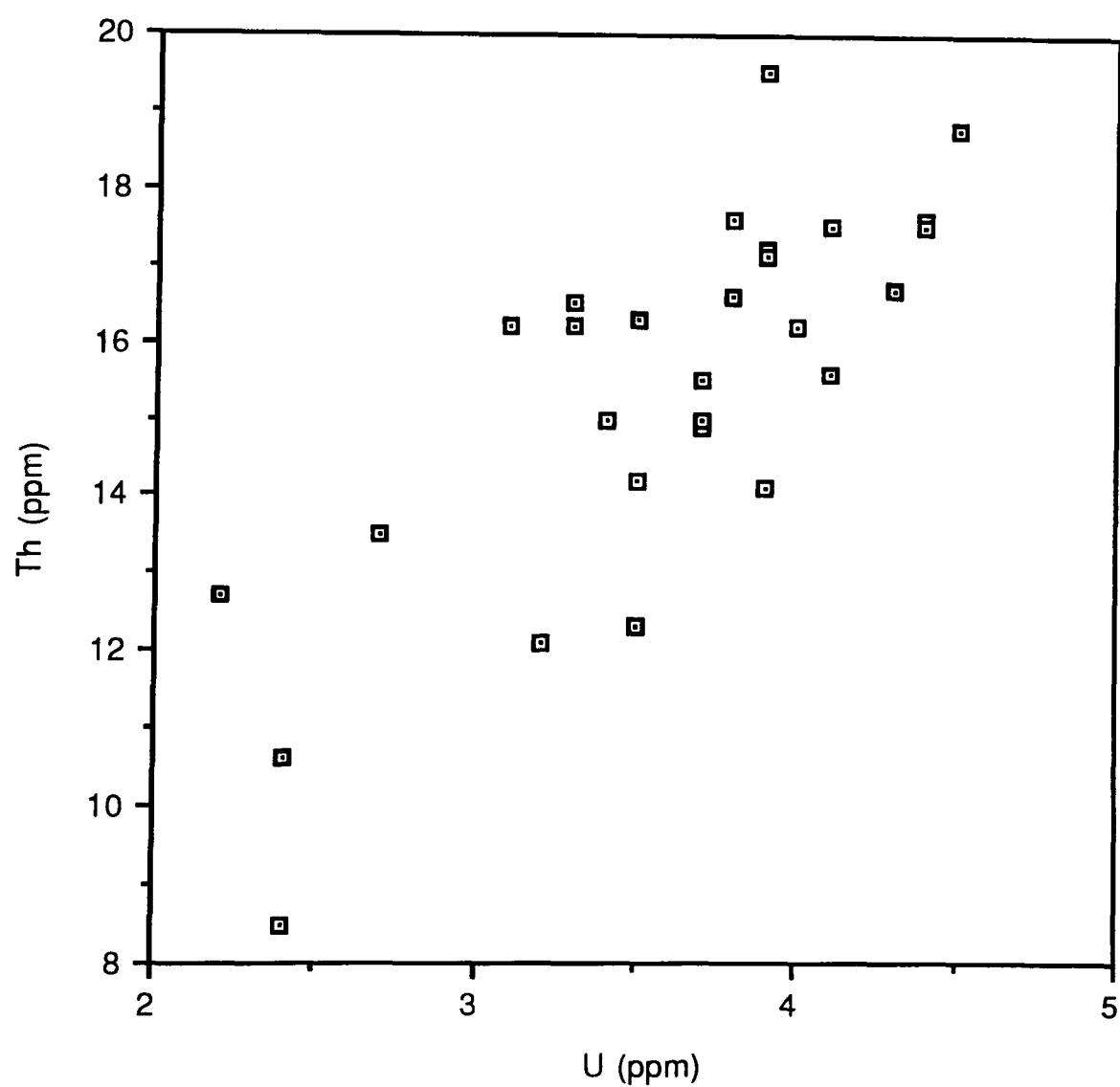


Figure 5.14b Th v. U for the Staithes Sandstone

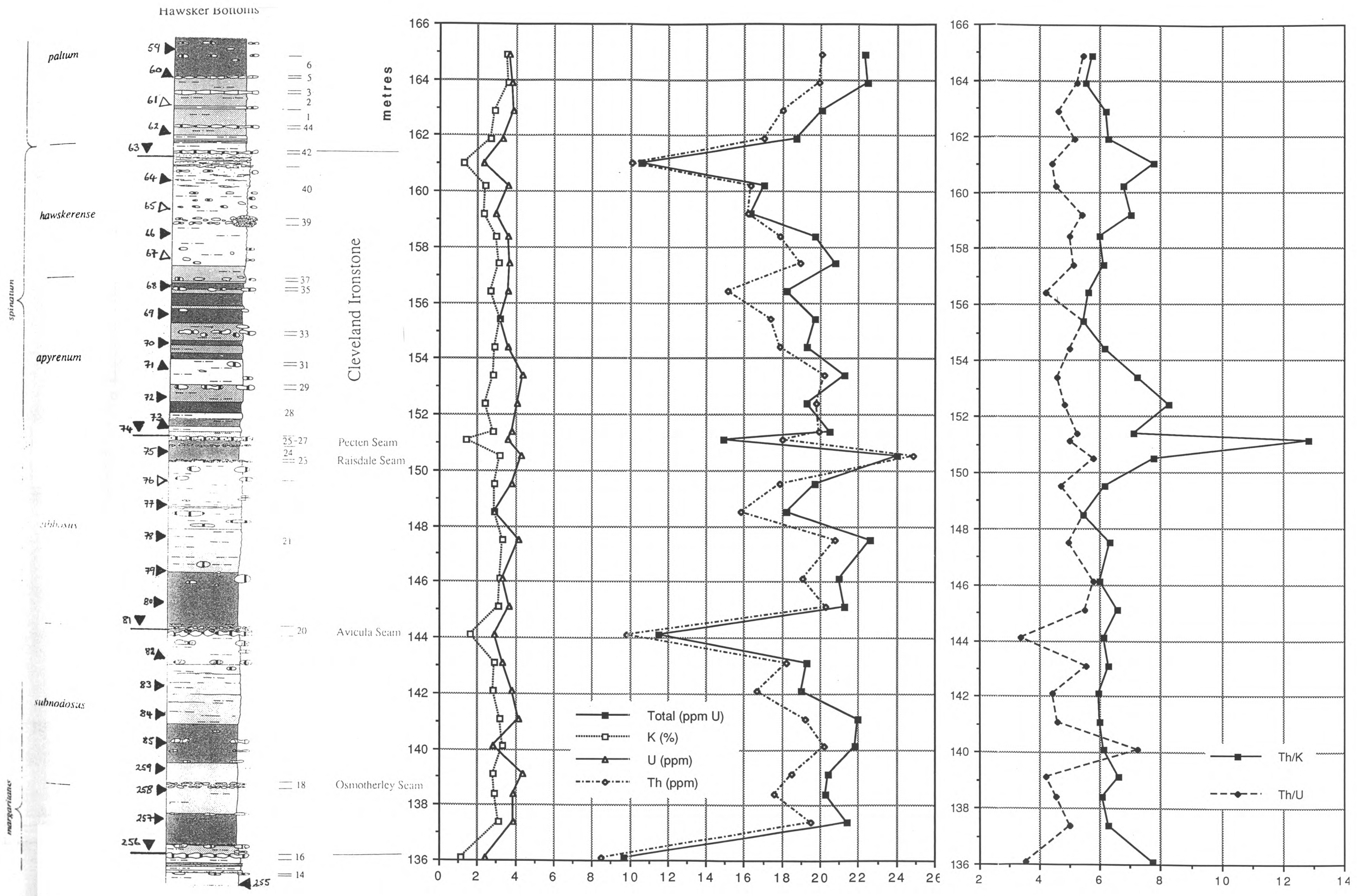


Figure 5.15 Cleveland Ironstone spectral gamma-ray data. Stratigraphic log from Hesselbo & Jenkyns (in press); see Appendix 1 for symbols used to describe gamma-ray measurement stations and for tabulated data.

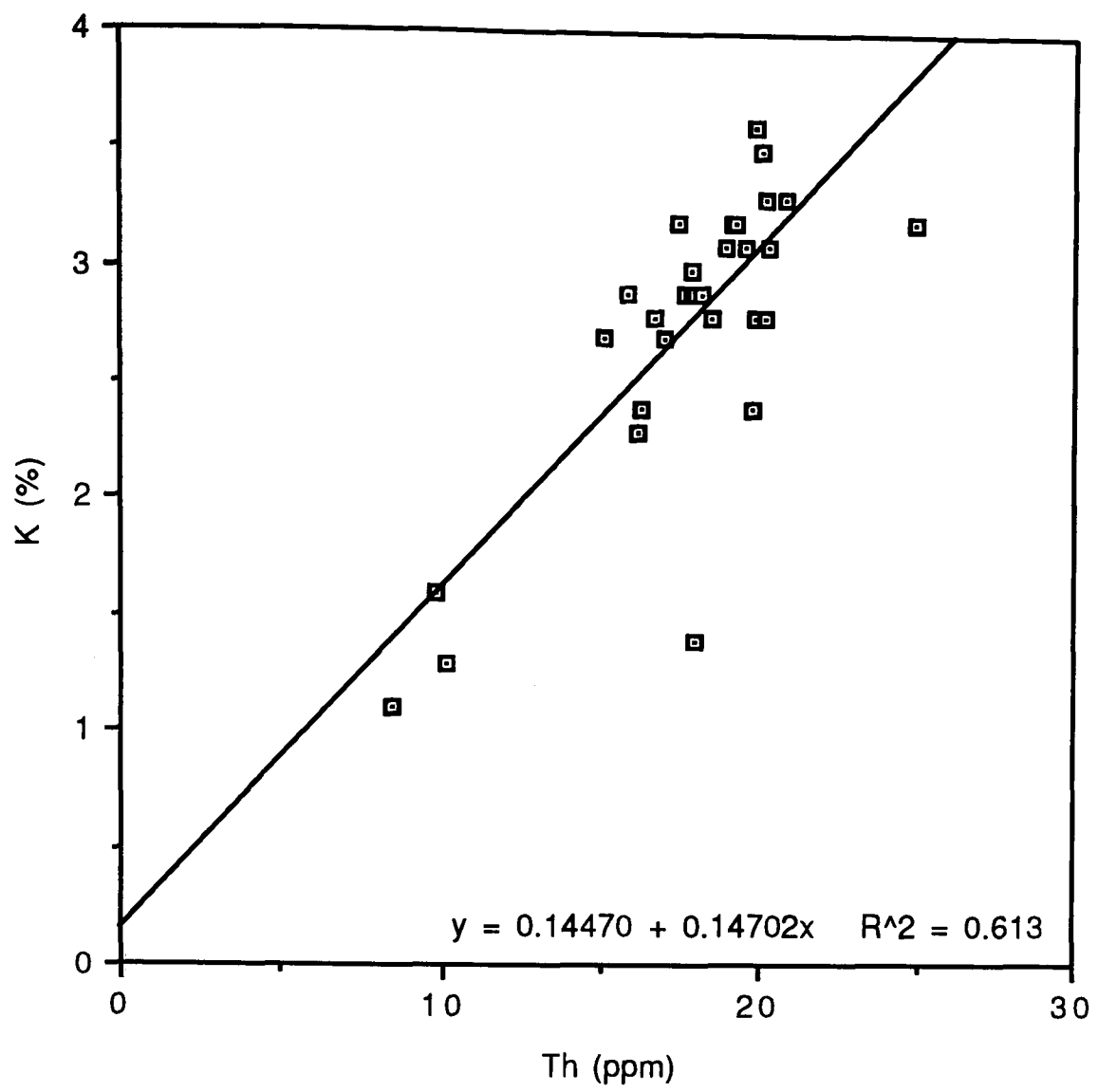


Figure 5.16a Th v. K for the Cleveland Ironstone

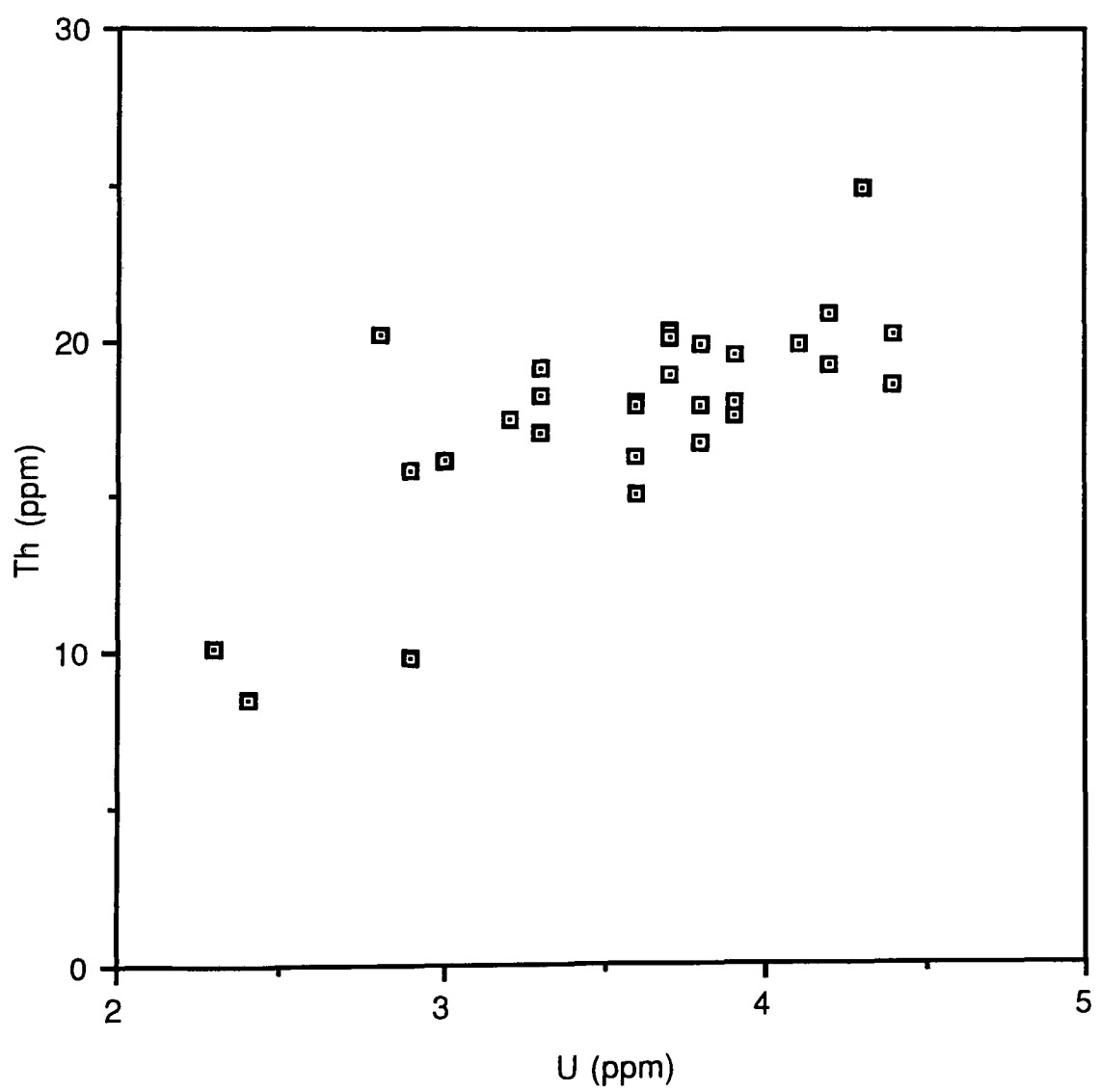


Figure 5.16b Th v. U for the Cleveland Ironstone

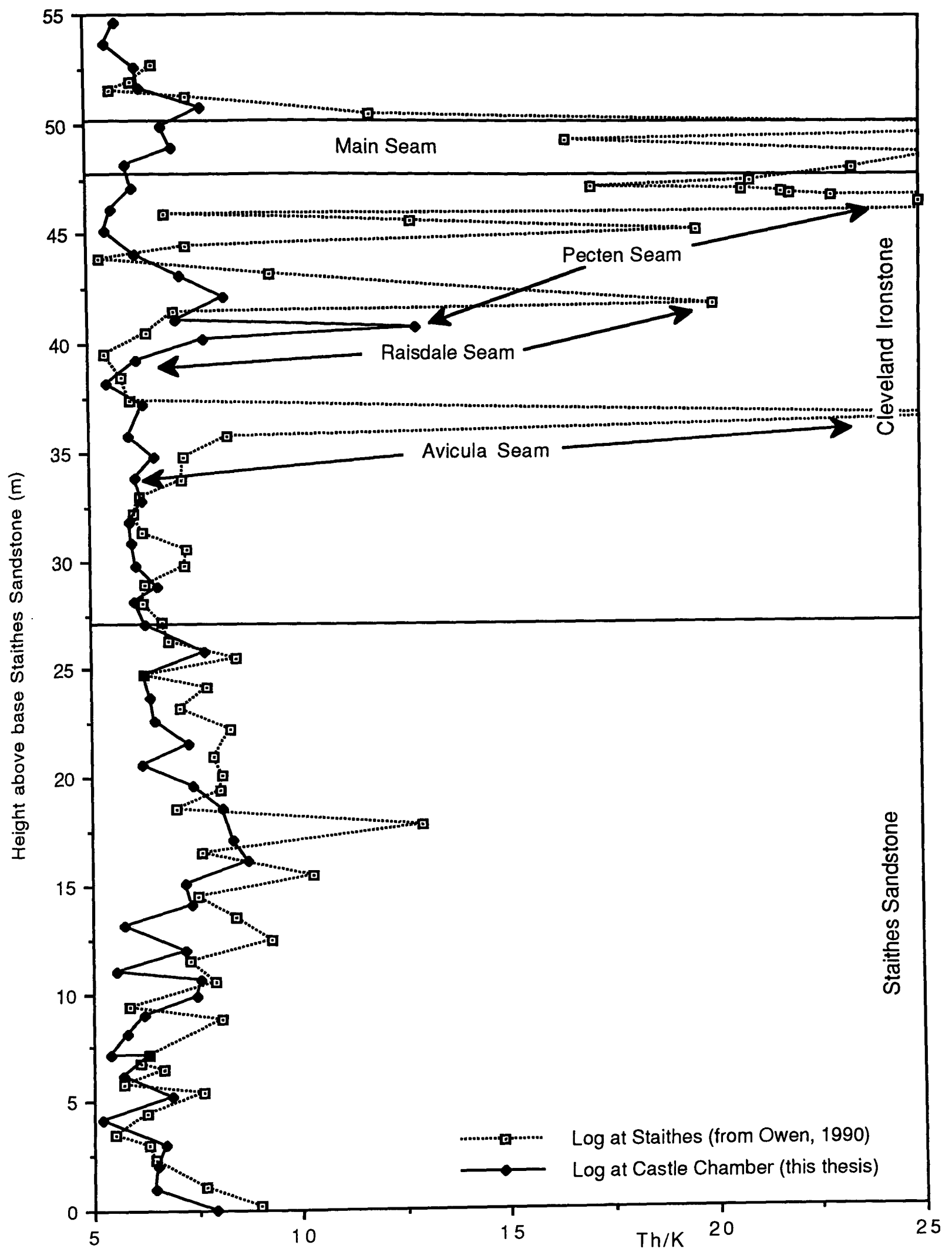


Figure 5.17 Comparison of Th/K data between Staithes and Castle Chamber (approx. 20km SE)

Hawsker Bottom

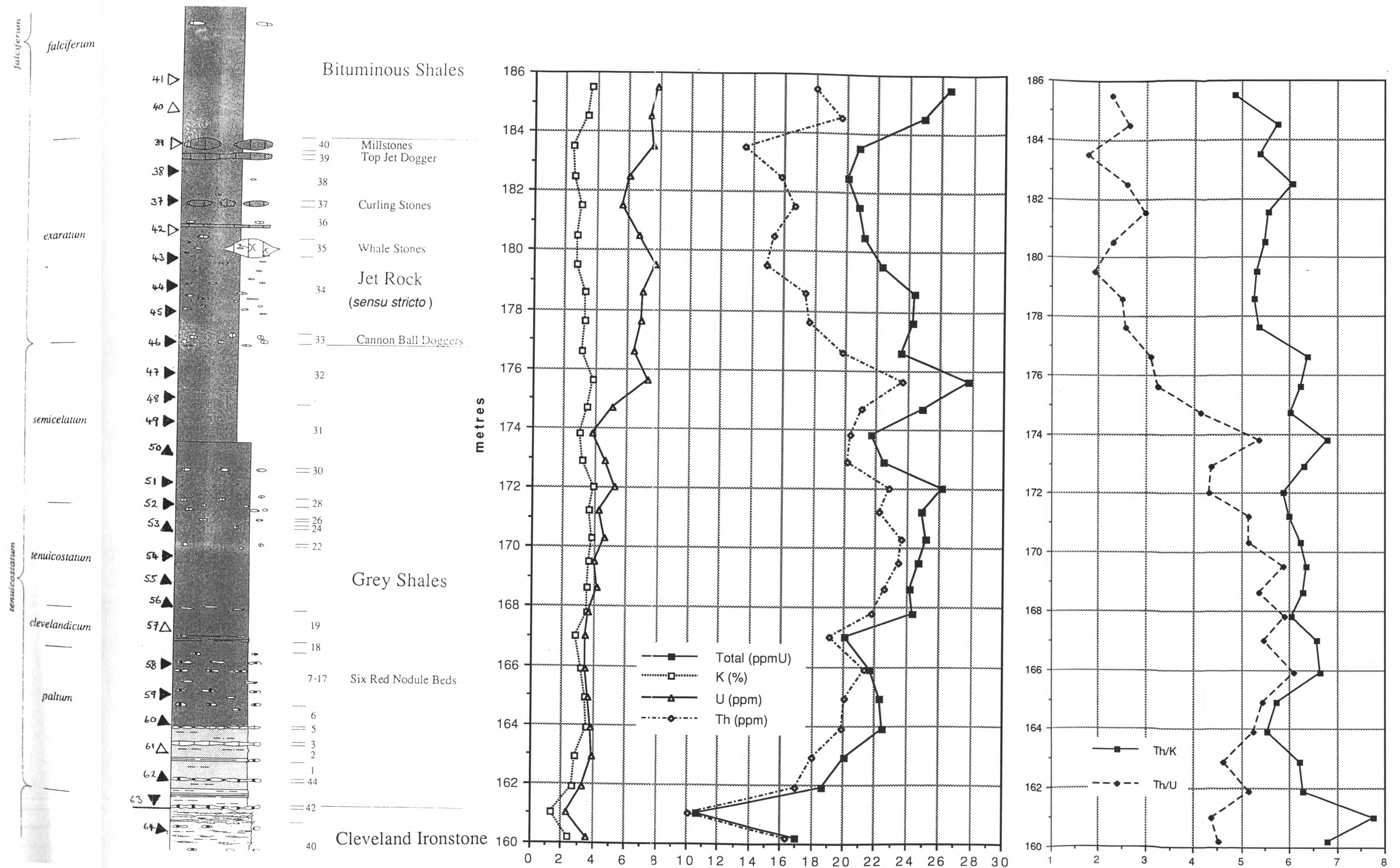


Figure 5.18 Grey Shales to Jet Rock (*sensu stricto*) spectral gamma-ray data. Stratigraphic log from Hesselbo & Jenkyns (in press); see Appendix 1 for symbols used to describe gamma-ray measurement stations and for tabulated data. Note that the Jet Rock (s.s.) forms the lower part of the Mulgrave Shale Member as proposed by Rawson & Wright (1992).

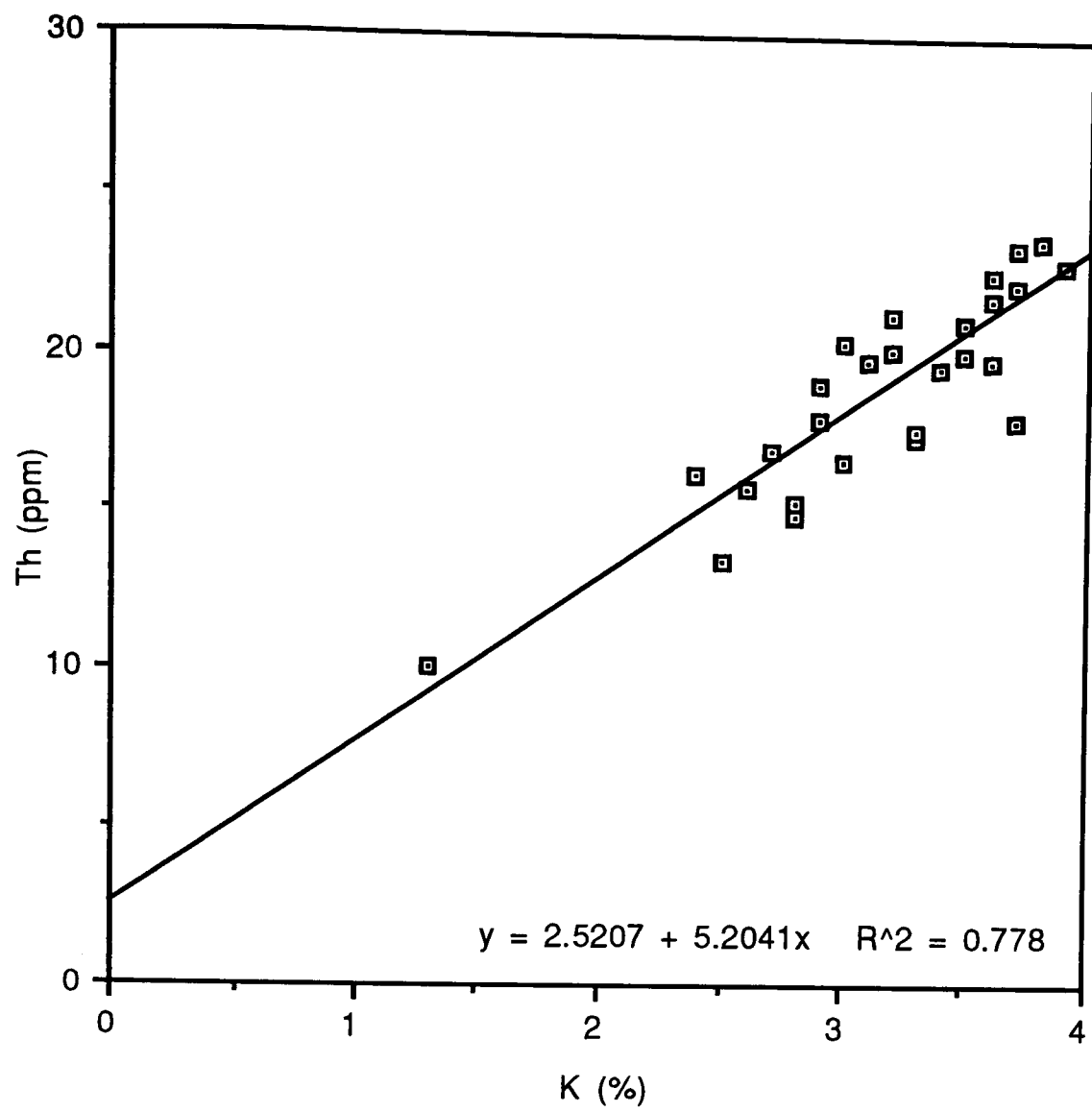


Figure 5.19a Th v. K for the Grey Shales-Jet Rock (s.s.) interval

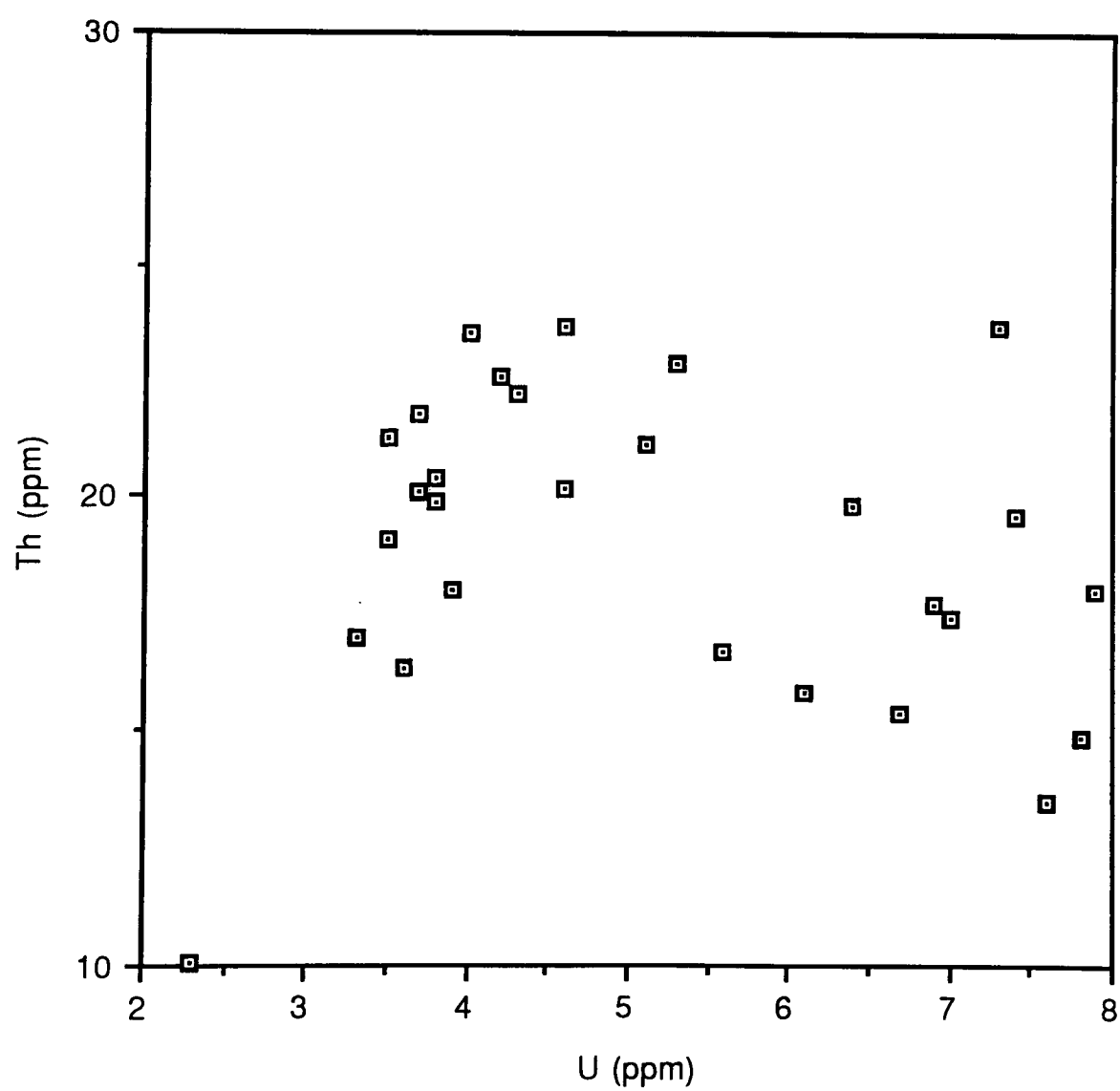


Figure 5.19b Th v. U for the Grey Shales-Jet Rock (s.s.) interval

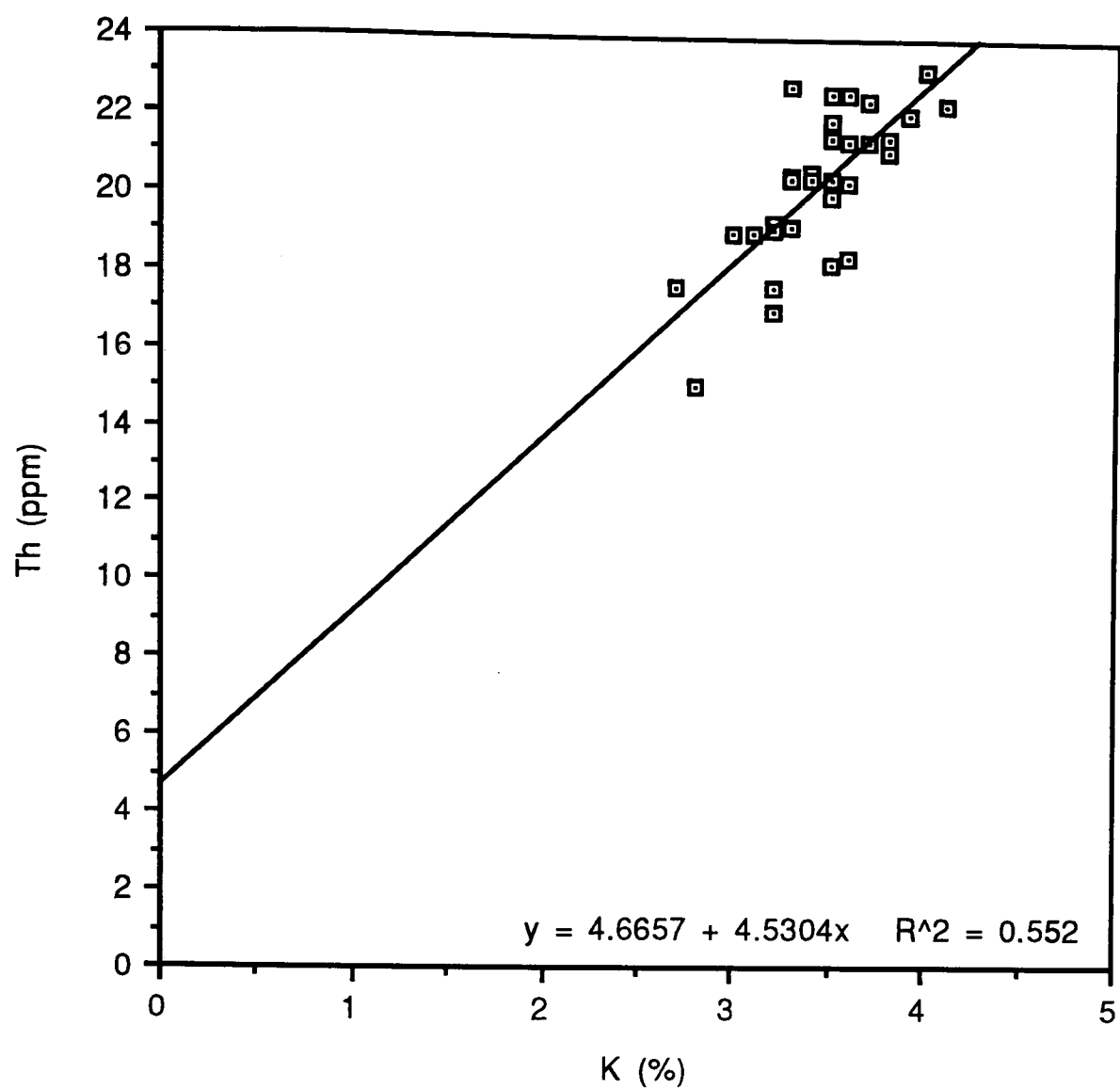


Figure 5.21a Th v. K for the Bituminous Shales-Main Alum Shales interval

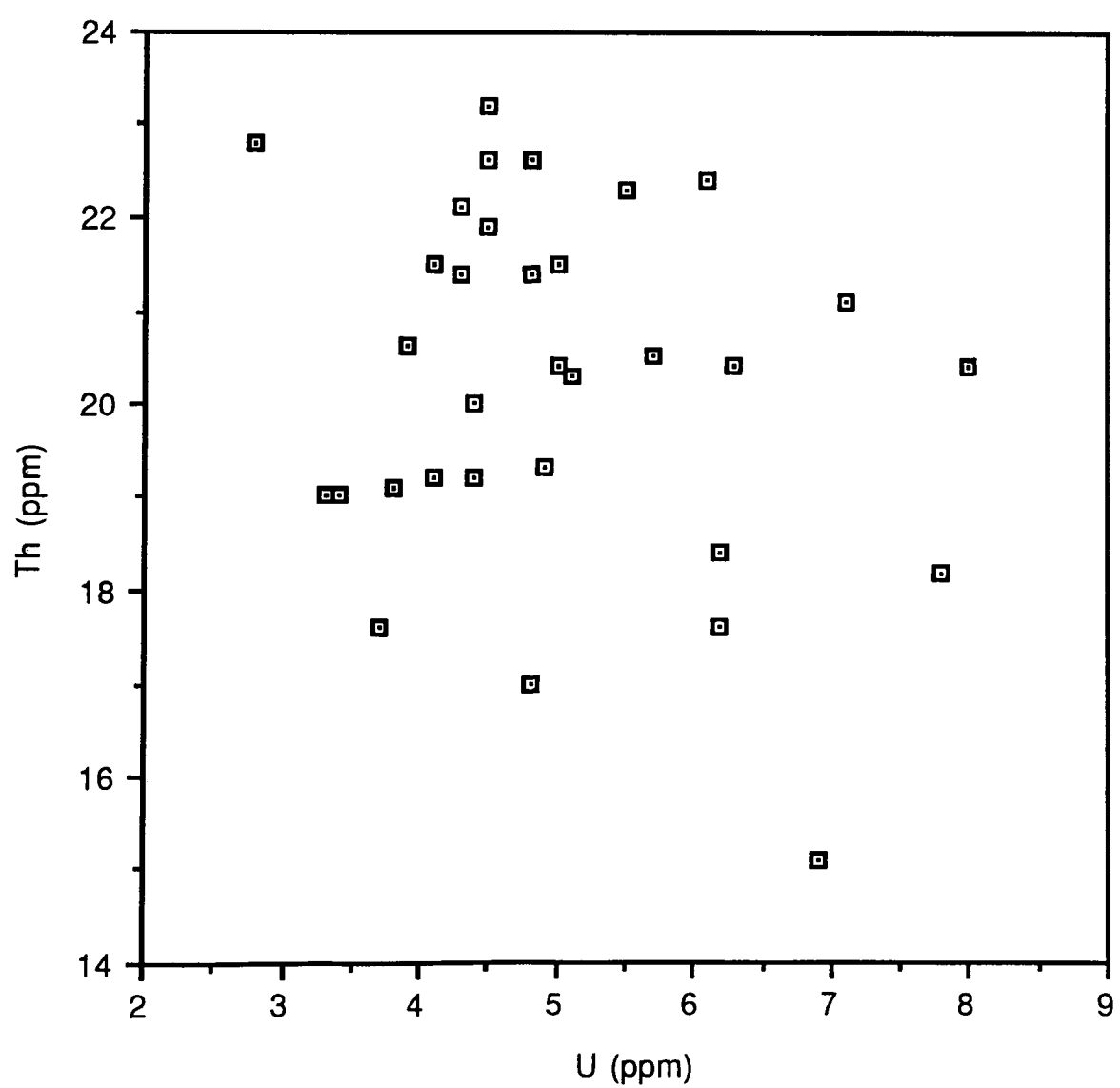


Figure 5.21b Th v. U for the Bituminous Shales-Main Alum Shales interval

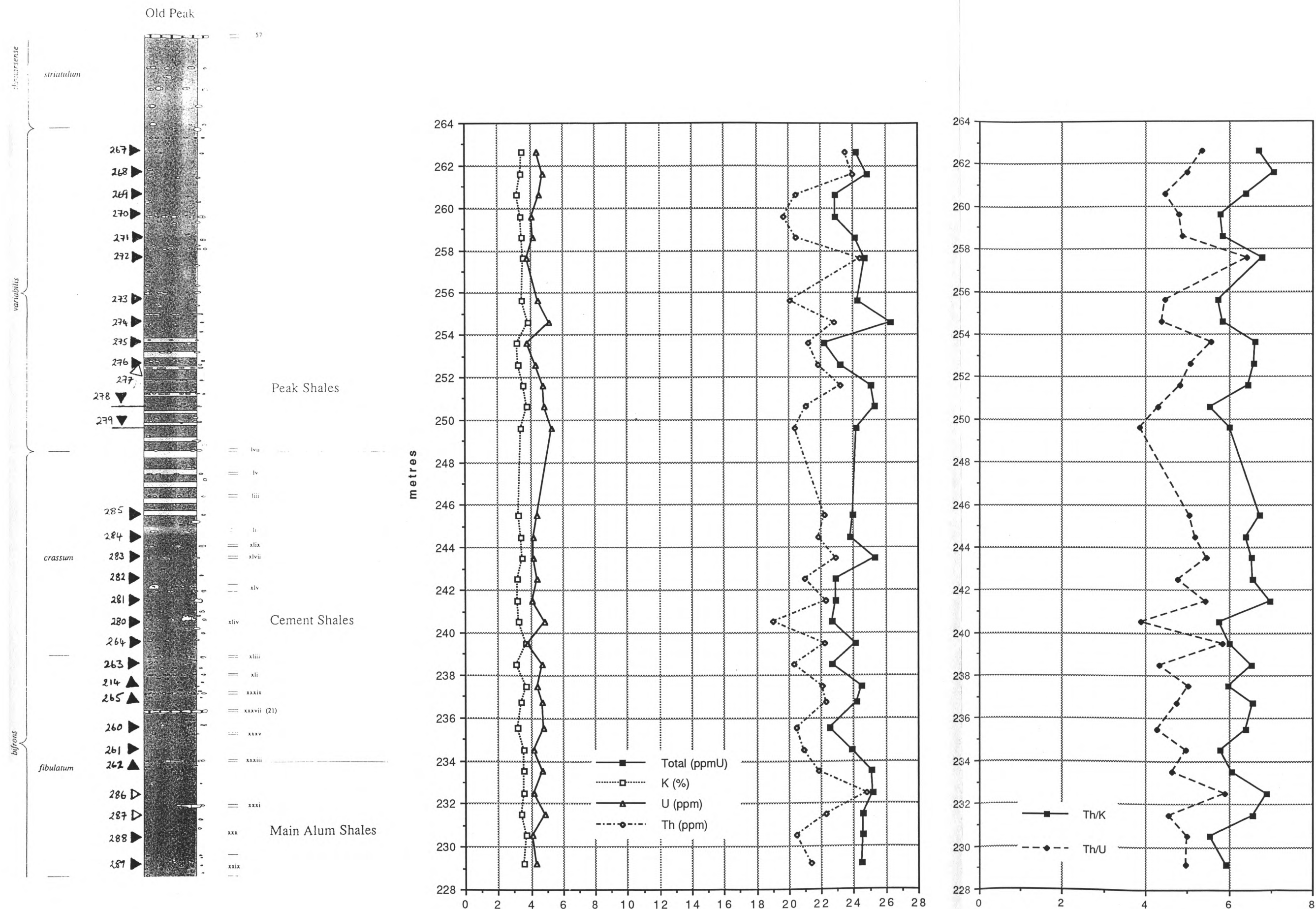


Figure 5.22 Main Alum Shales to Peak Shales spectral gamma-ray data. Stratigraphic log from Hesselbo & Jenkyns (in press); see Appendix 1 for symbols used to describe gamma-ray measurement stations and for tabulated data. The subdivision of the Alum Shales into the Main Alum Shales and the Cement Shales is as used by Howarth (1962).

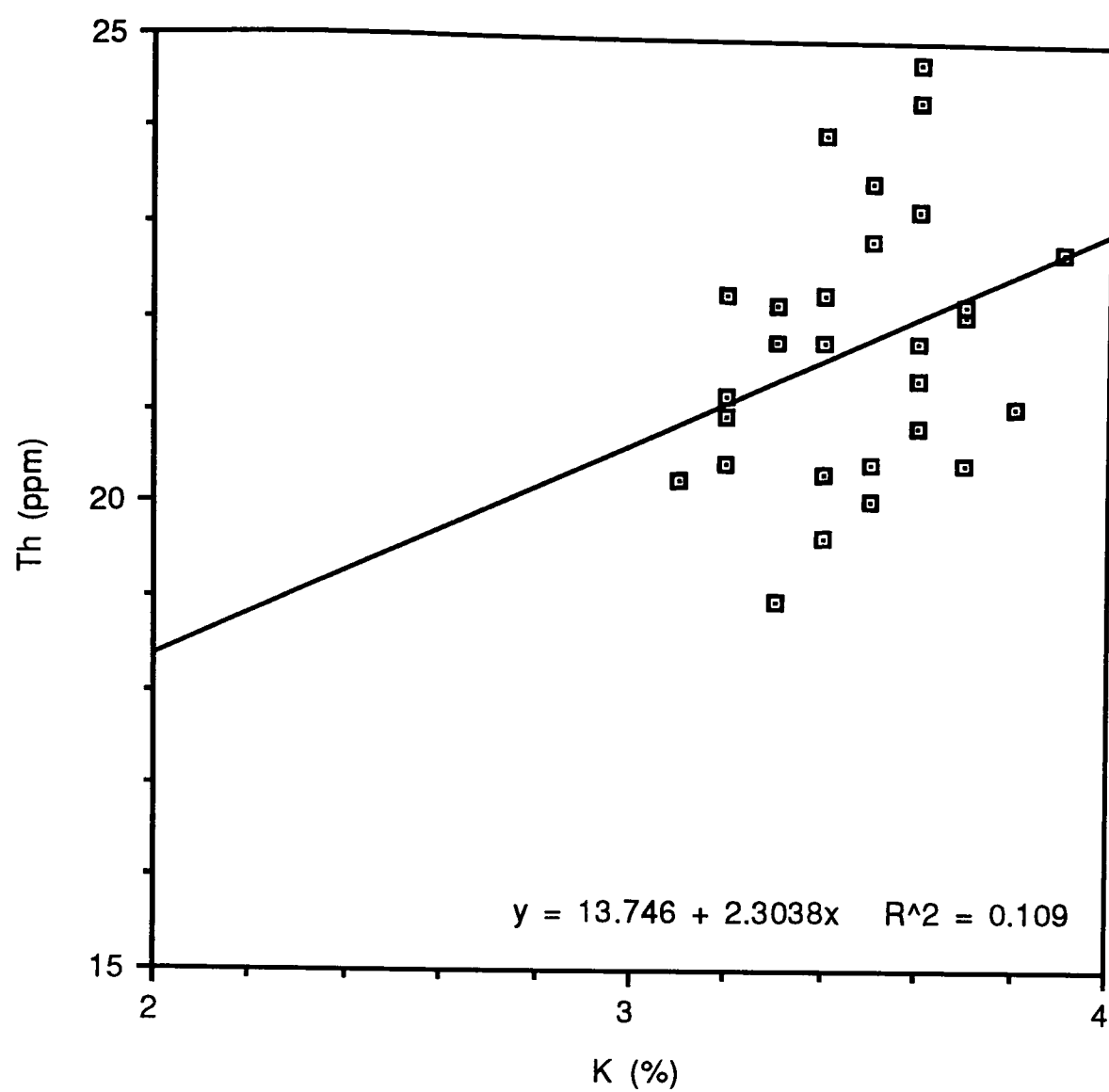


Figure 5.23a Th v. K for the Cement Shales and Peak Shales

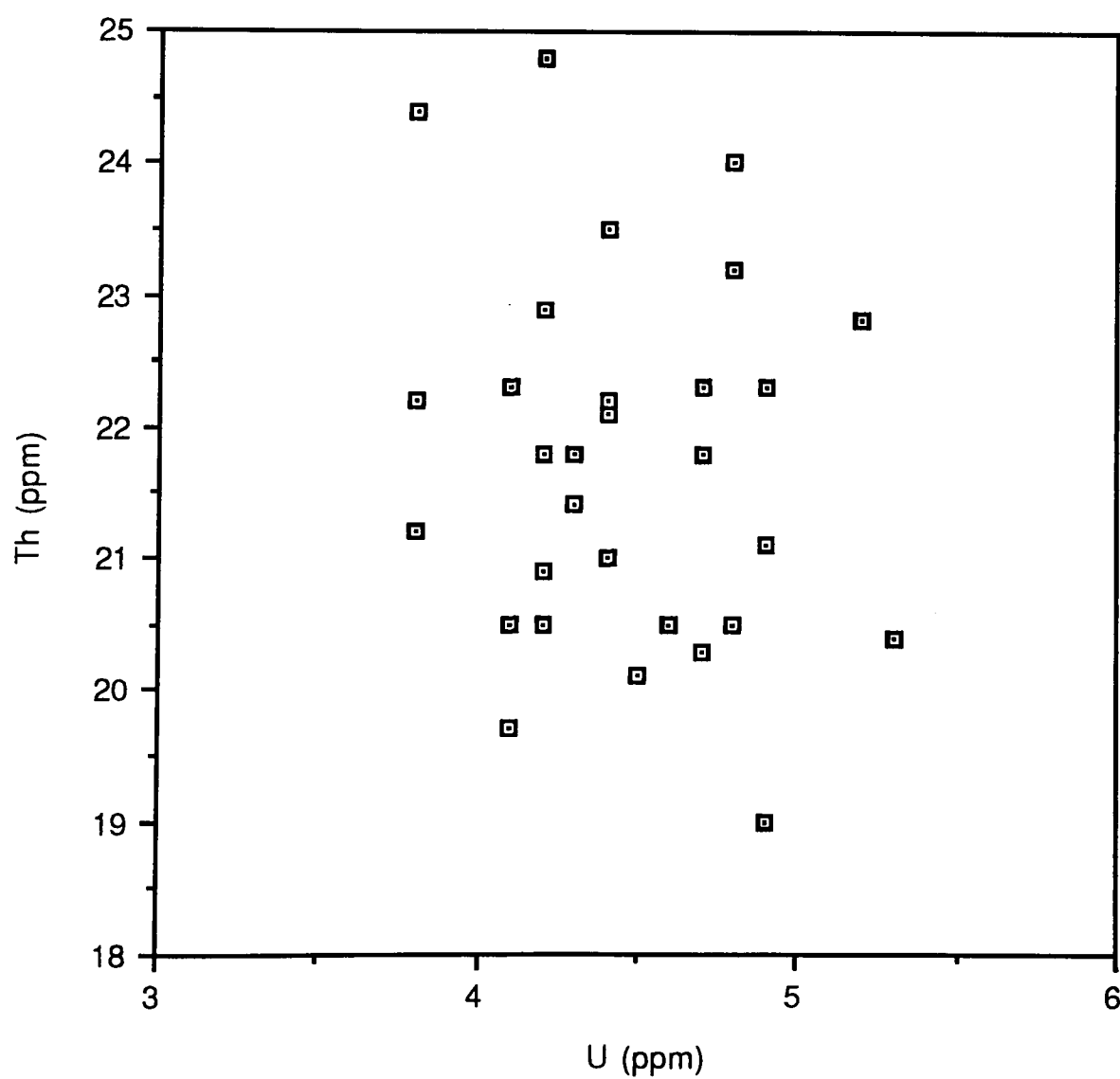


Figure 5.23b Th v. U for the Cement Shales and Peak Shales

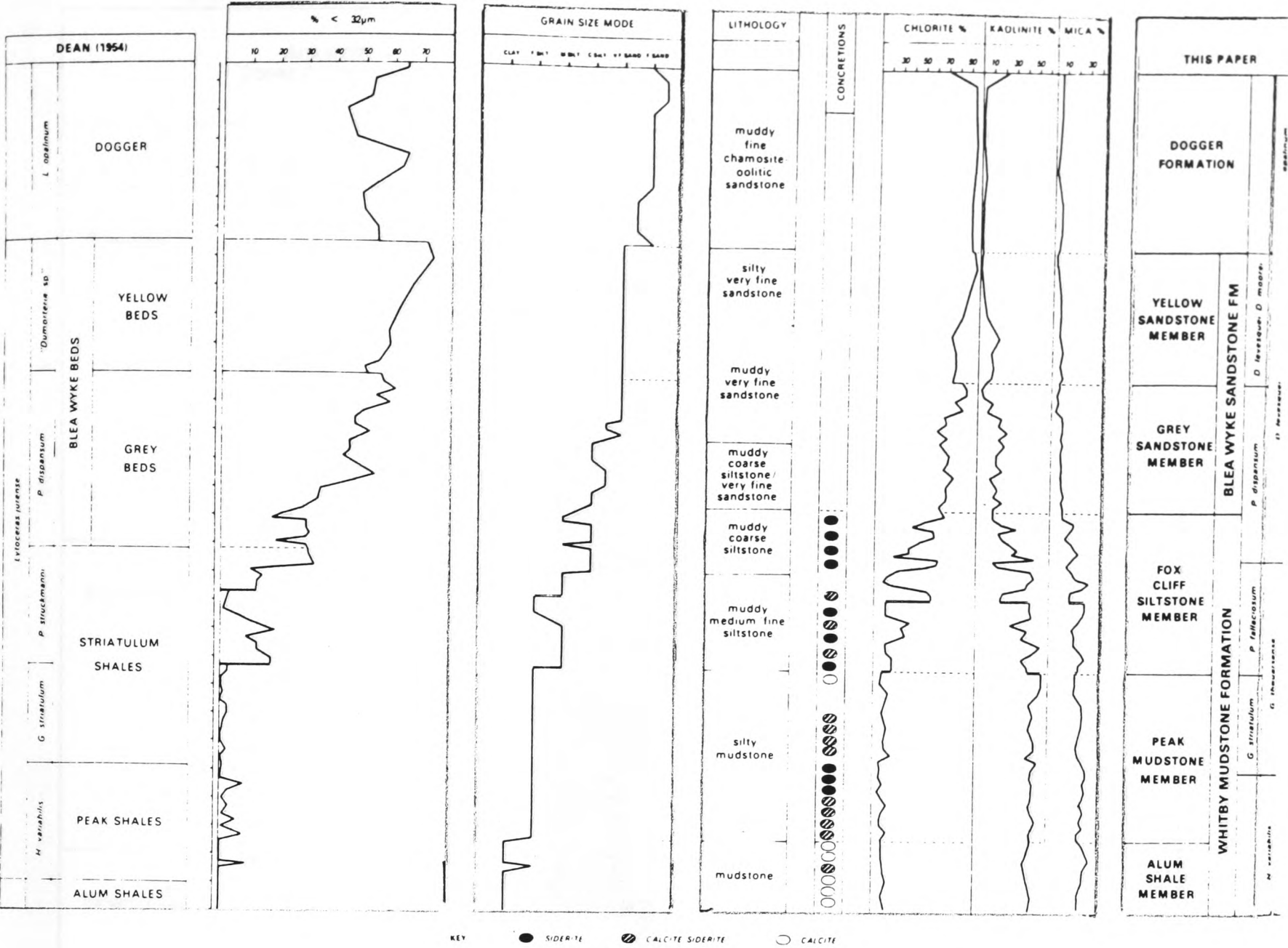


Figure 5.24 Peak Shales to Dogger: grainsize and clay mineralogy (from Knox, 1984)

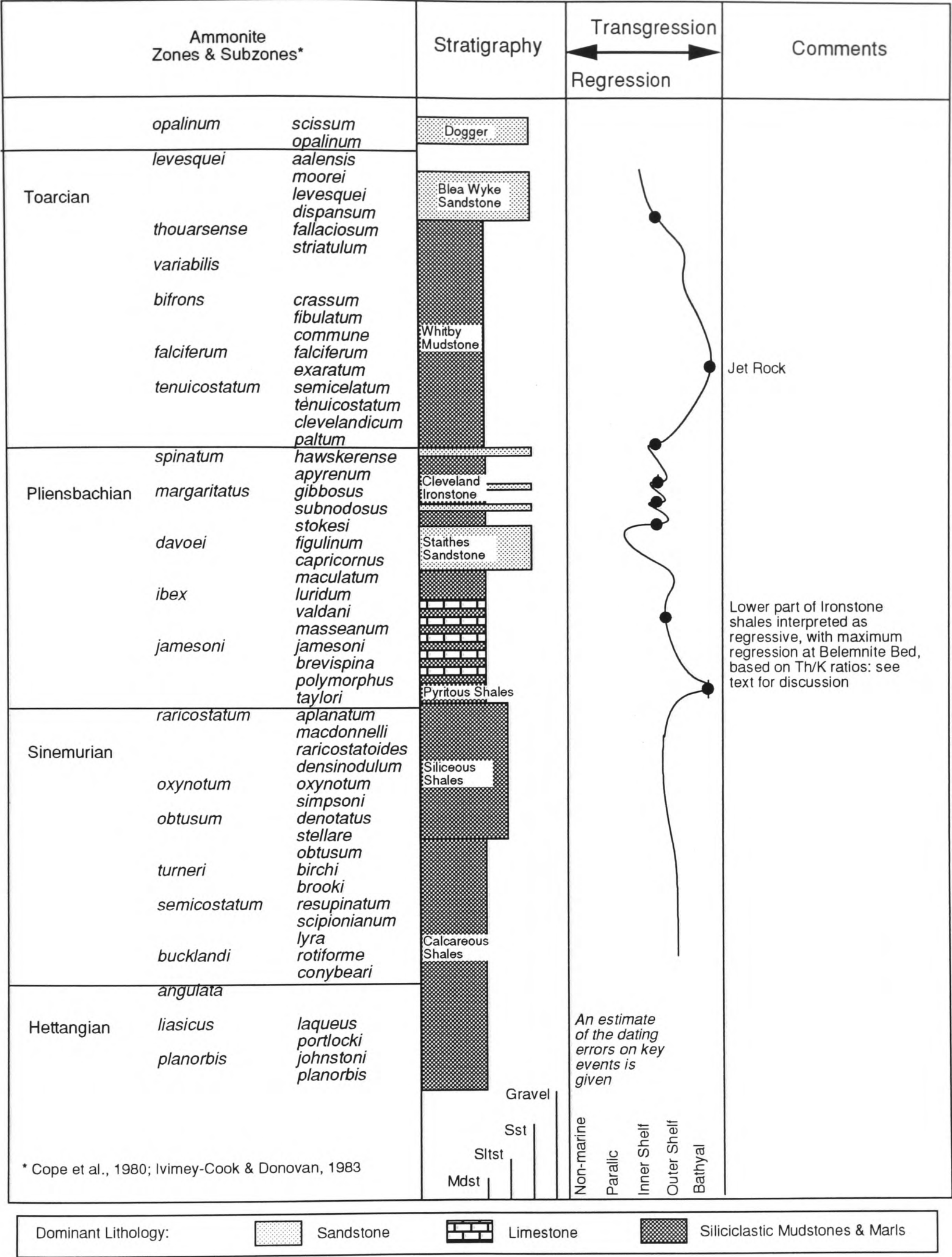


Figure 5.25 Summary of stratigraphic events in the Lower Jurassic of Yorkshire, England

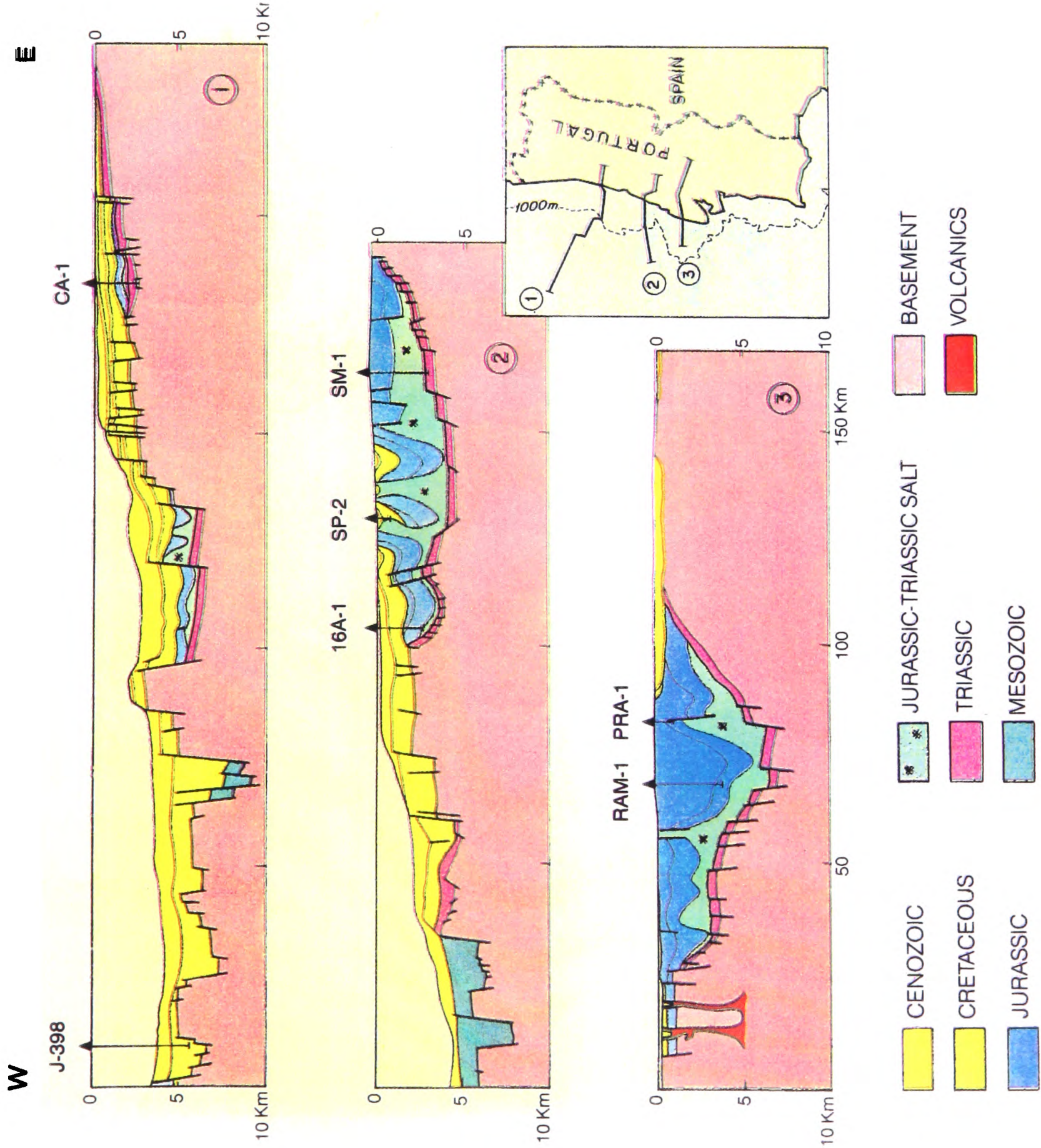


Figure 6.1 The Lusitanian Basin illustrated by serial cross-sections (from Ziegler, 1988).

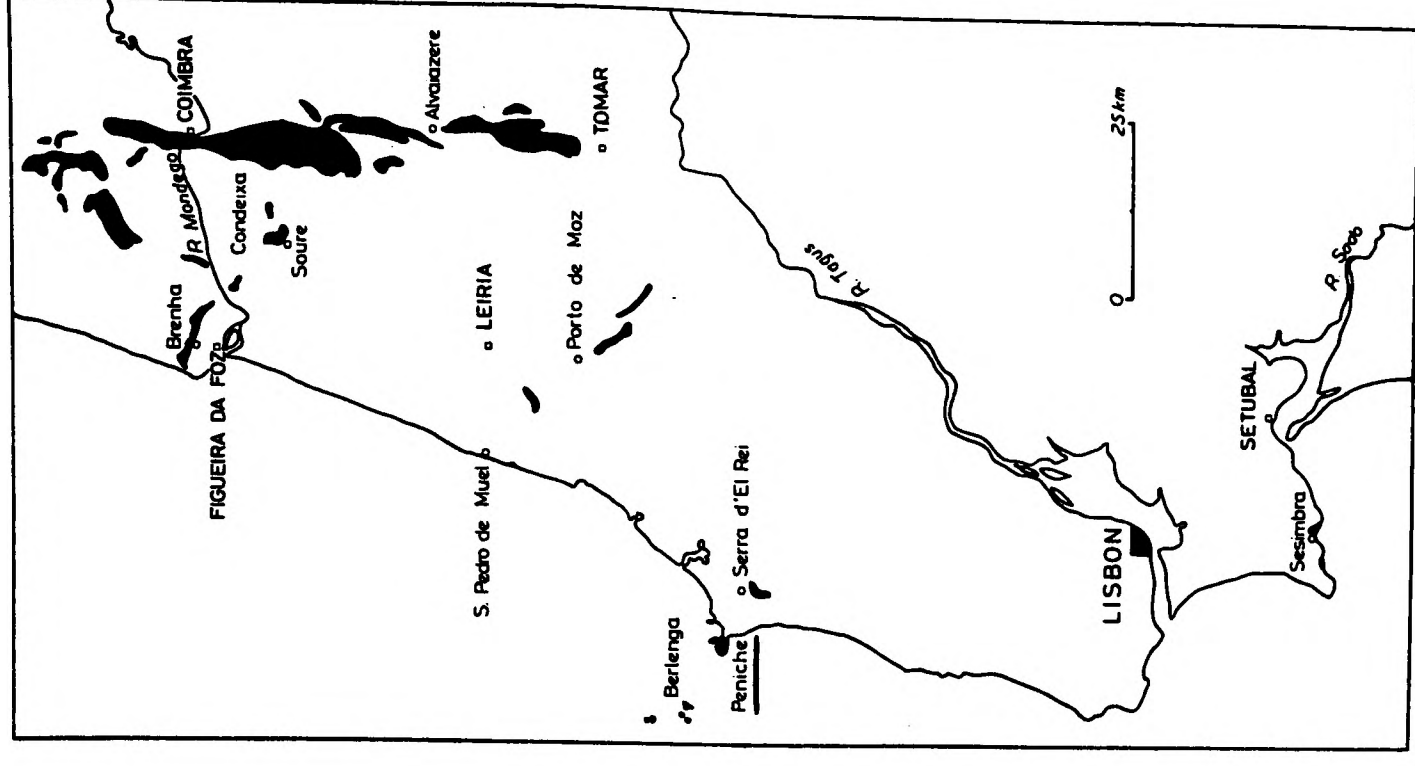


Figure 6.2 Lusitanian Basin: outcrops of the Lower Jurassic (from Hallam, 1971, after Mouterde, 1967)

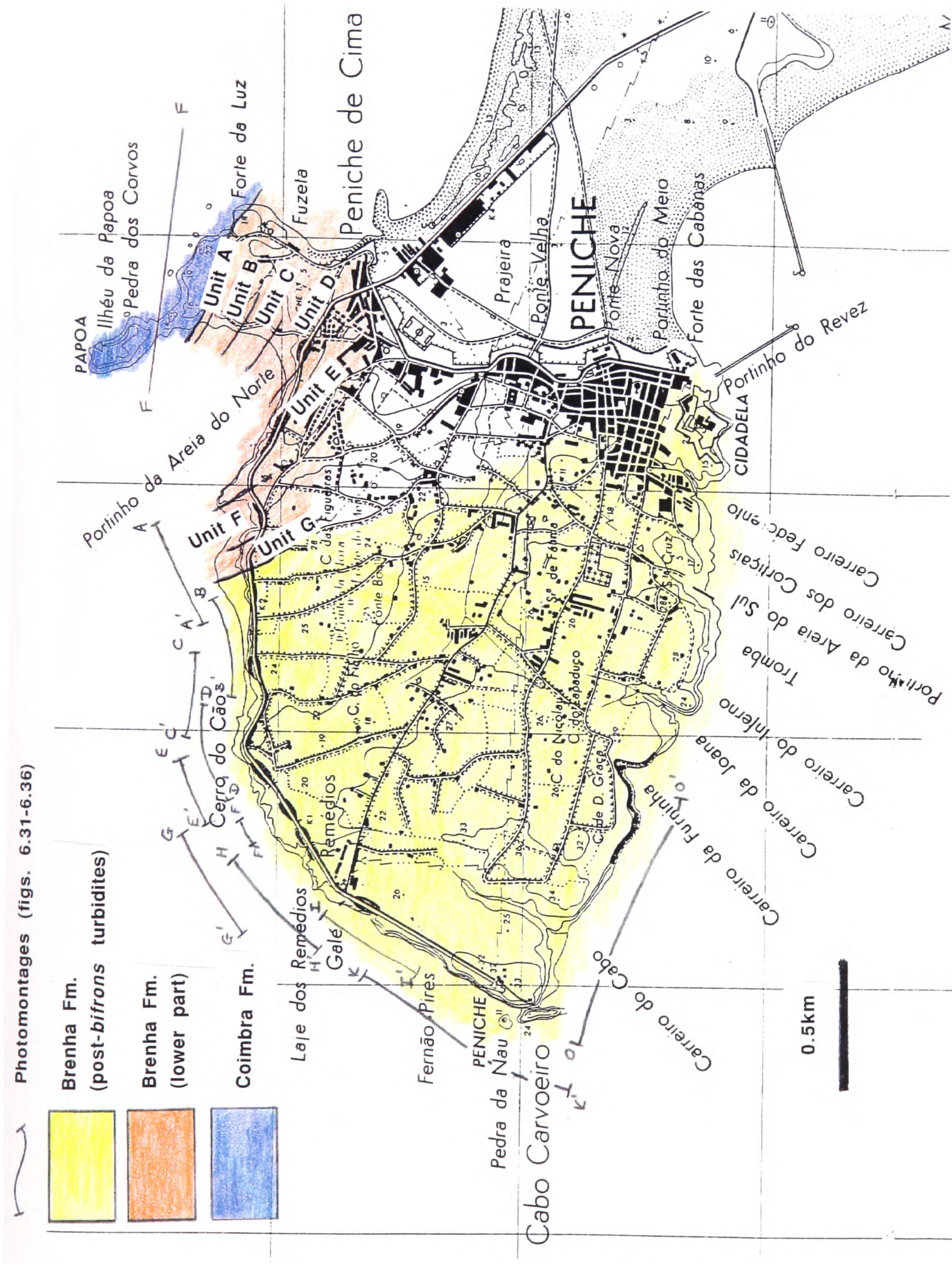


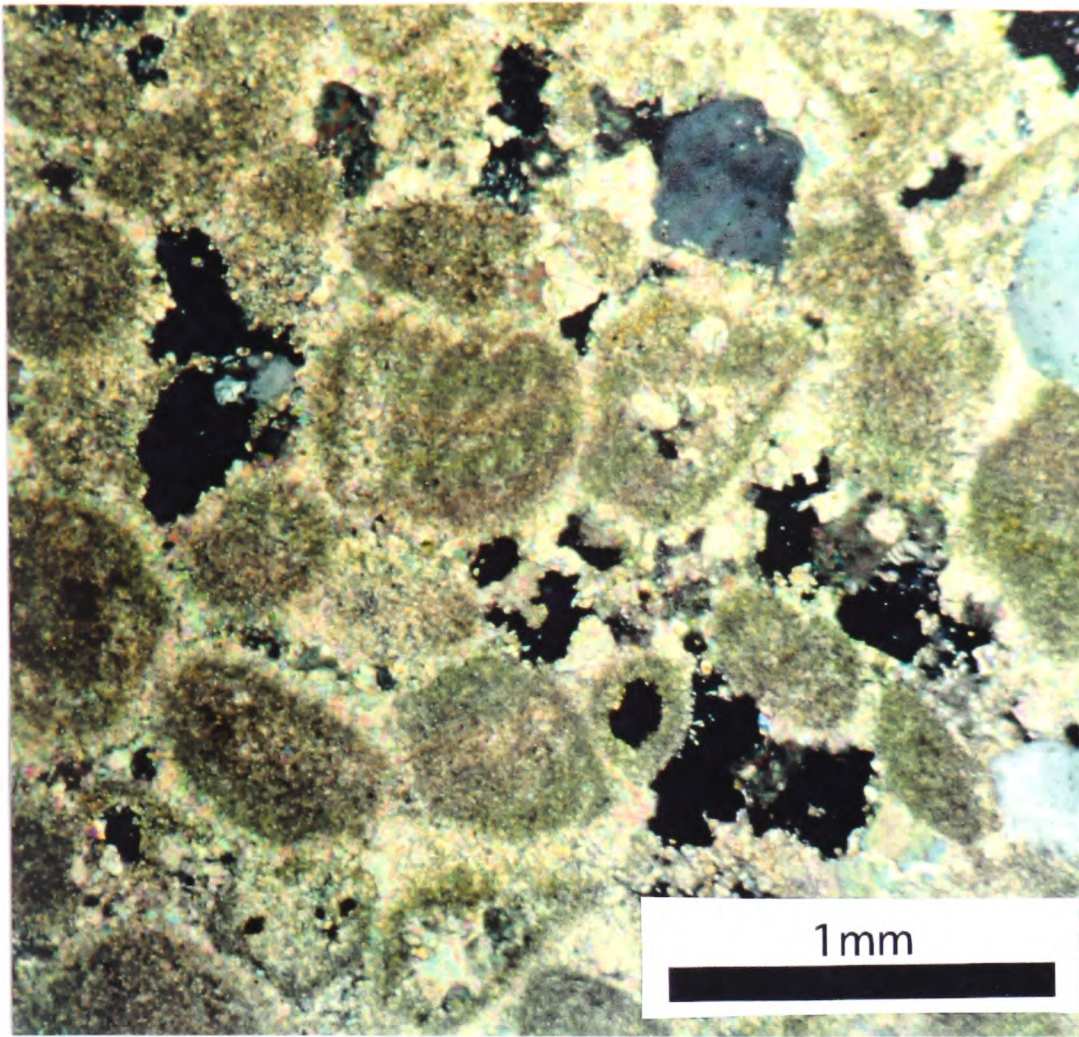
Figure 6.3 The Peniche Peninsula: localities and geology (based on Serviço Cartográfico do Exército, Carta Militar de Portugal, 1:25,000)



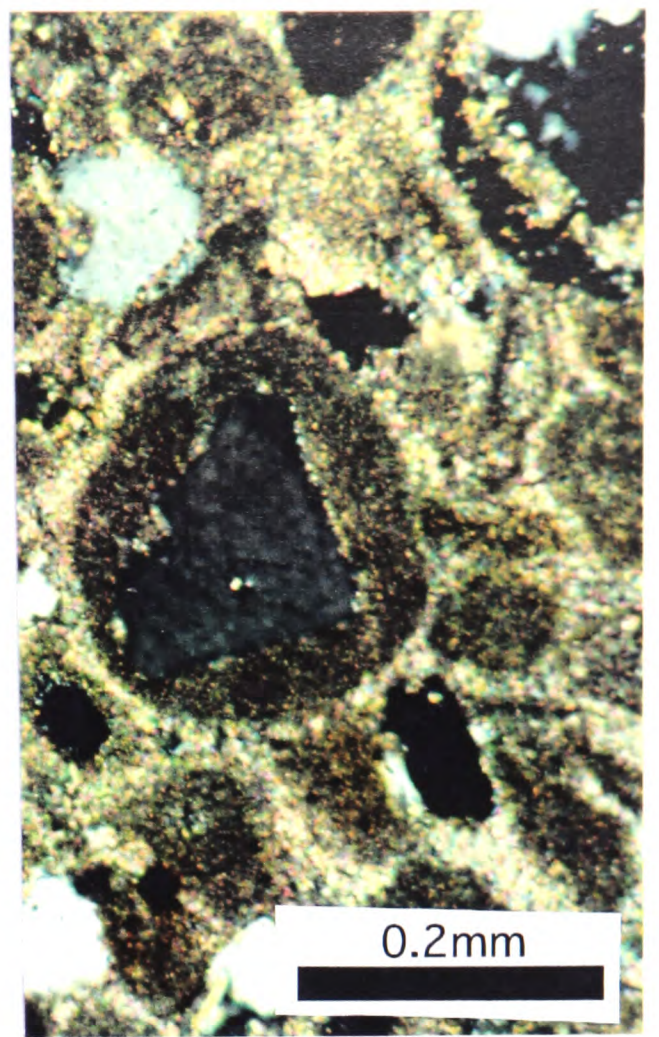
Figure 6.4a Top of the Coimbra Formation west of the Papoa peninsula
(hardground which marks the top of the Coimbra is arrowed)



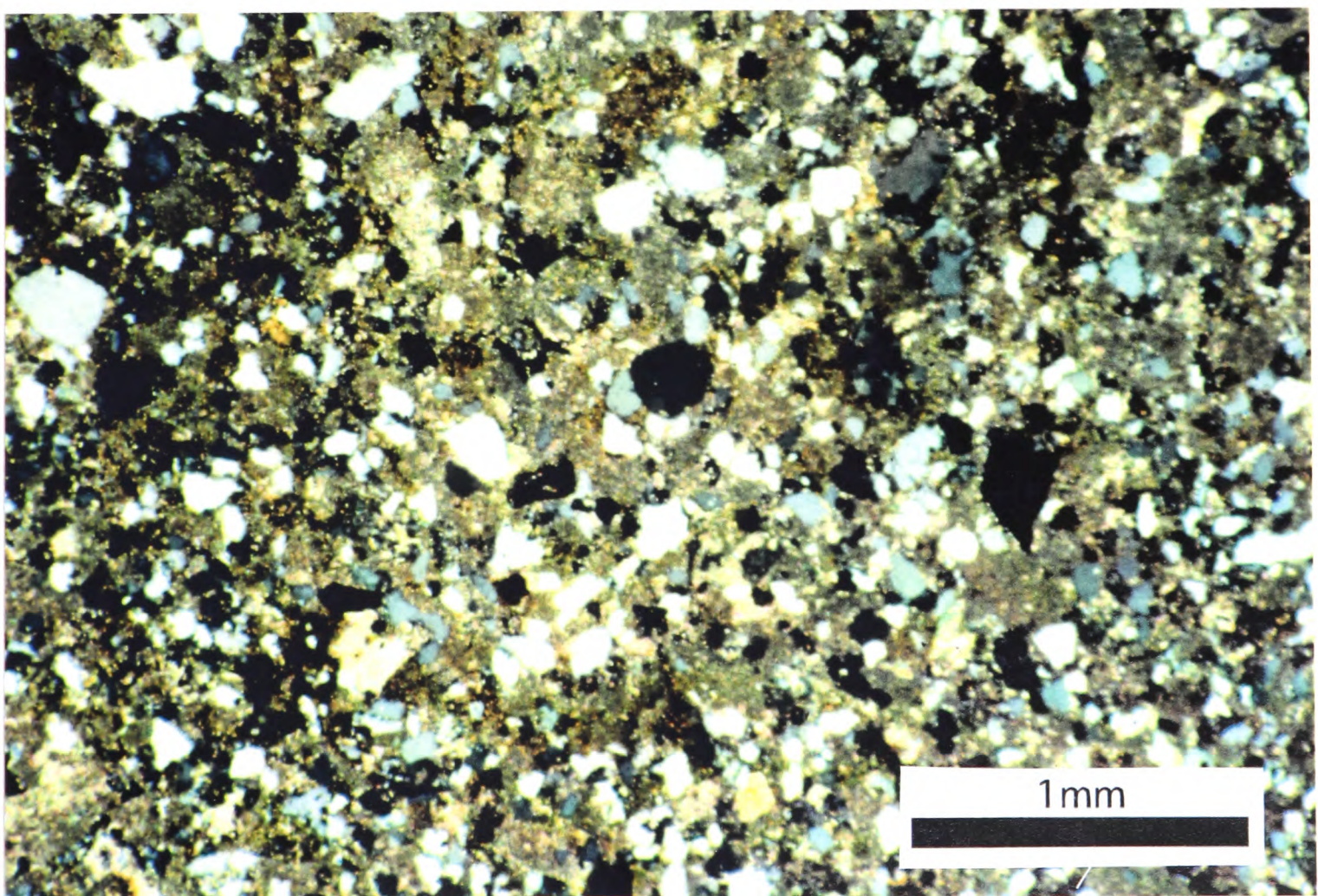
Figure 6.4b Top of the Coimbra Formation east of the Papoa peninsula
(hardground which marks the top of the Coimbra is arrowed)



a) Peloidal grainstone (sample 2PW62, xpl)



b) As (a), showing detail of quartz-cored peloid



c) Sandstone (sample 2PW70, xpl)

Figure 6.5 Microfacies of the Coimbra Formation

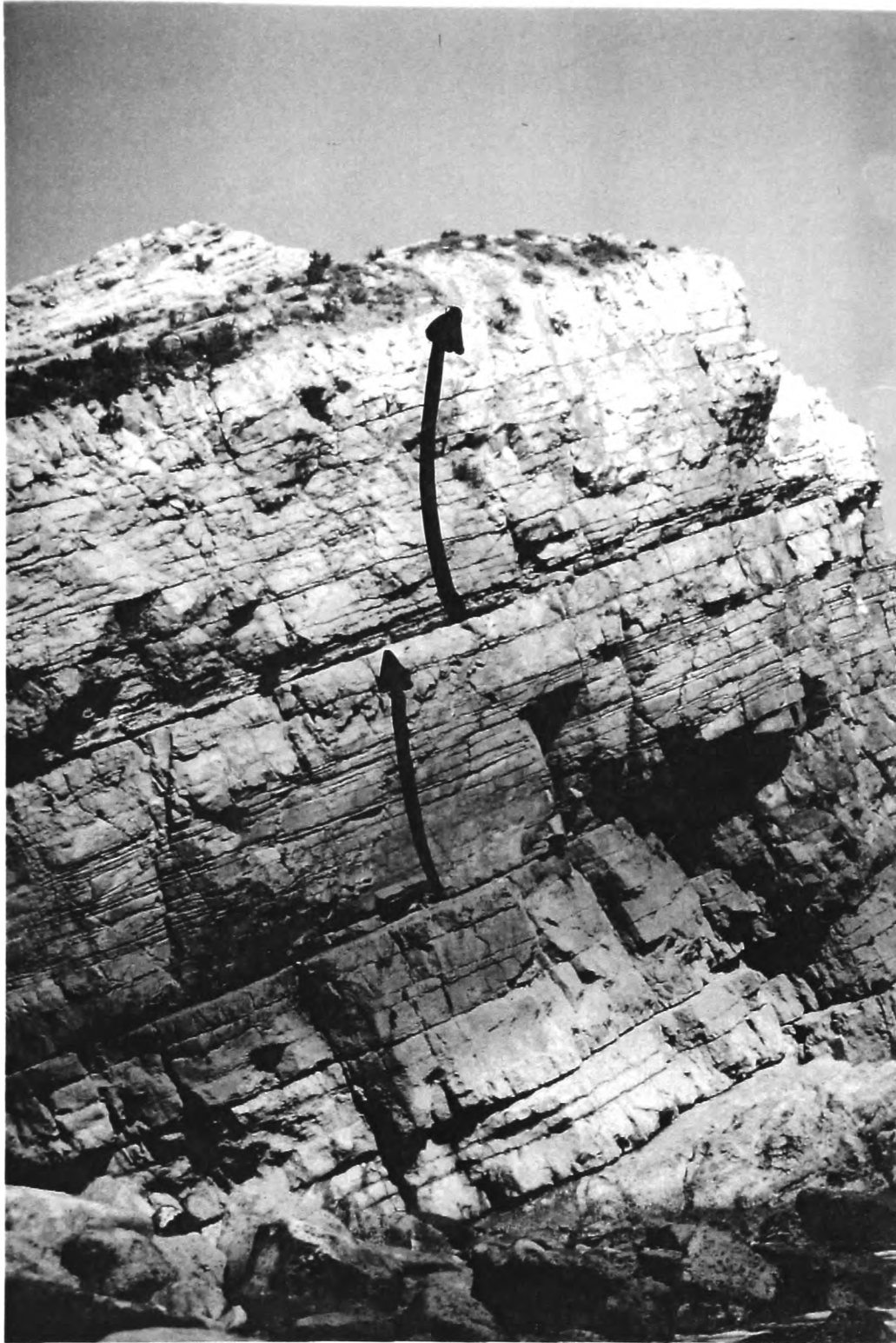


Figure 6.6 Thickening-upwards cycles at the top of the Coimbra Fm., east side of Papoa (compare arrows with log, fig. 6.7)



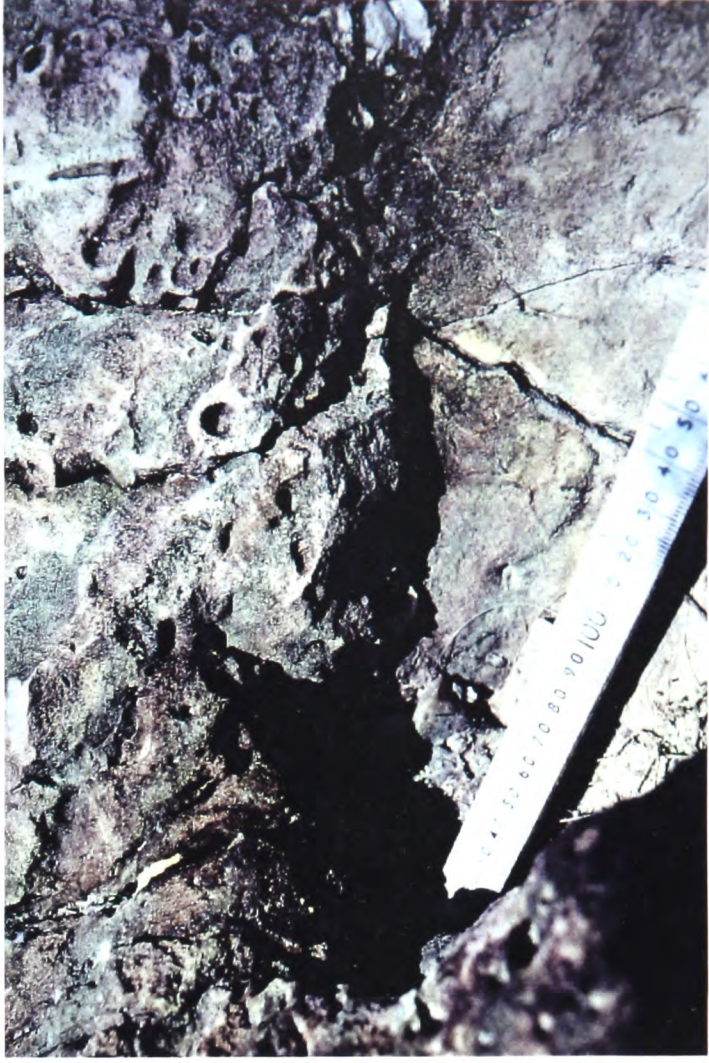
a) Oyster with serpulid encrustation



b) Serpulids encrusting hardground



c) Semi-circular scours: possible resting traces of fish (see text)



d) Detail of scours showing bivalve borings inside and hence demonstrating that the scours are primary features

Figure 6.8 Features of the top Coimbra Fm hardground, west side of Papoa

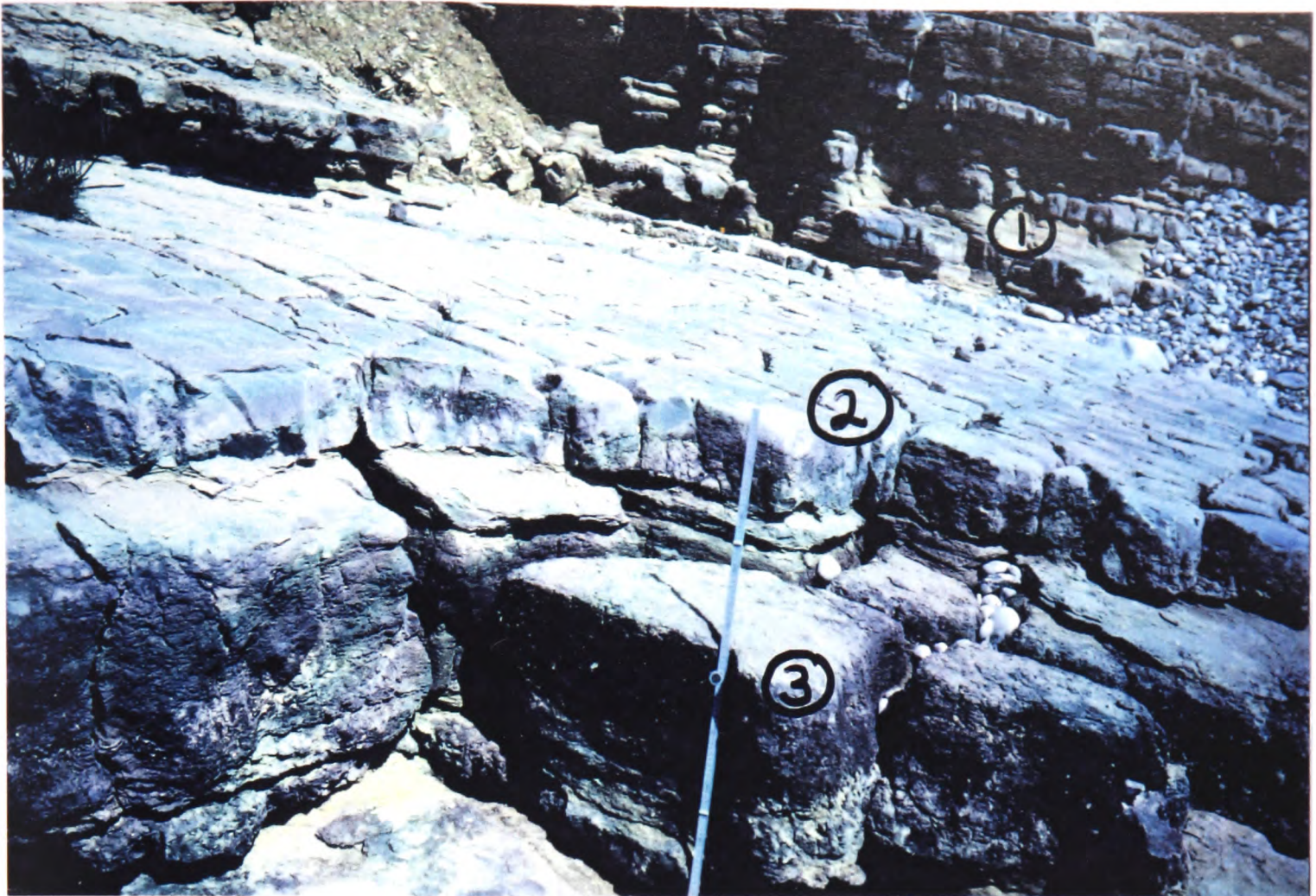


Figure 6.9a General aspect of Brenha Formation, Unit A. Facies 1, 2, & 3 are discussed in text

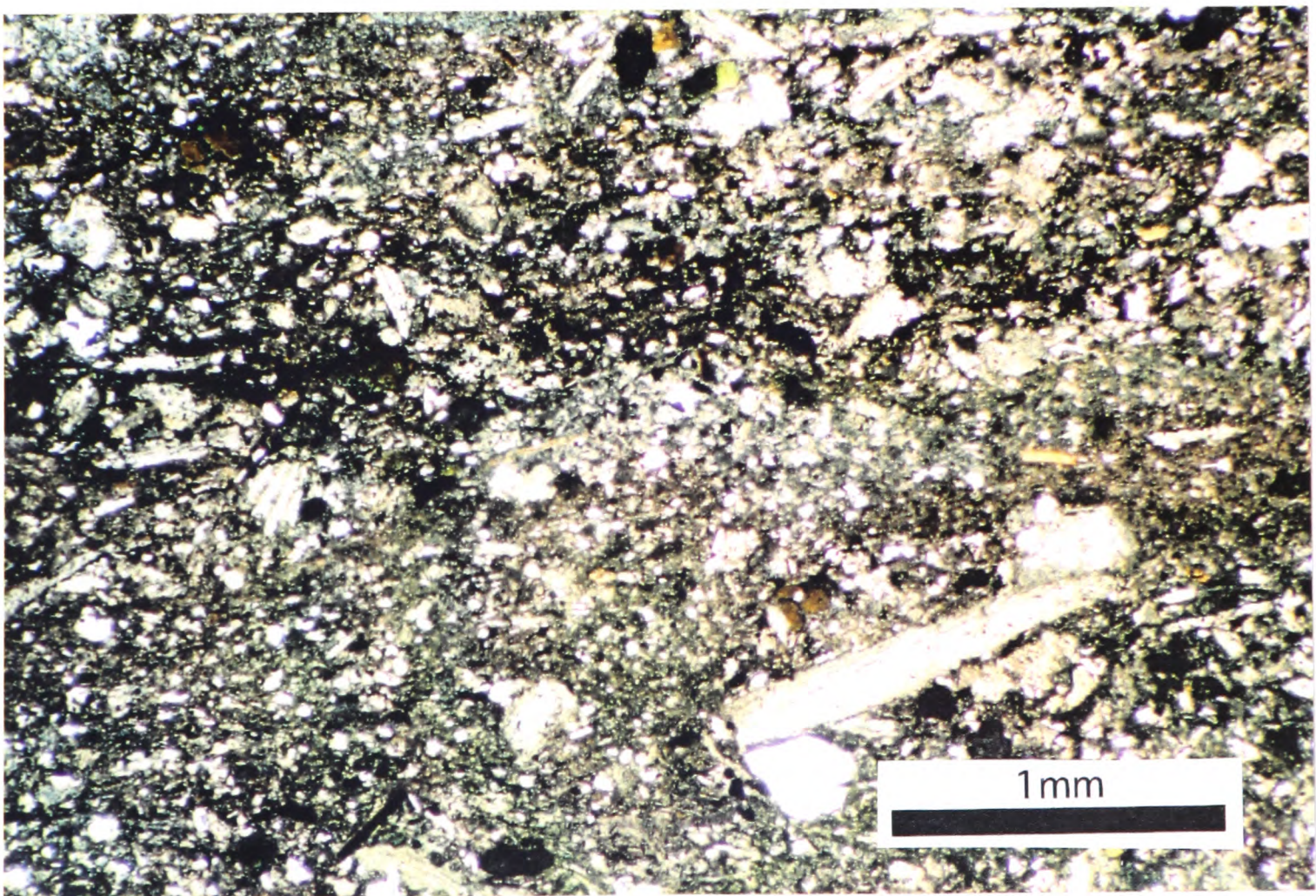


Figure 6.9b Photomicrograph of facies 1, argillaceous, bioclastic packstone/wackestone

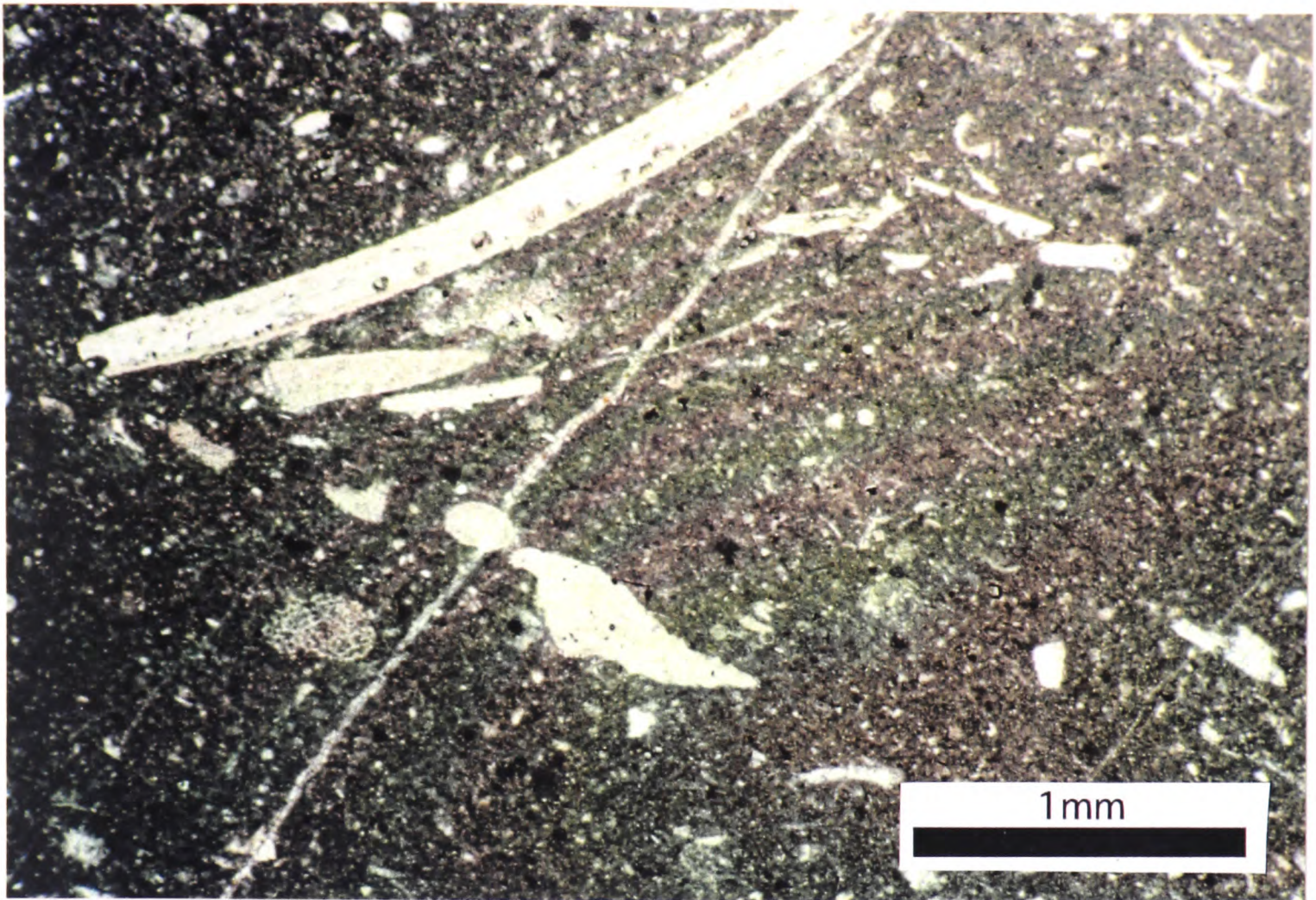


Figure 6.10a Photomicrograph of facies 2, bioclastic lime mudstone

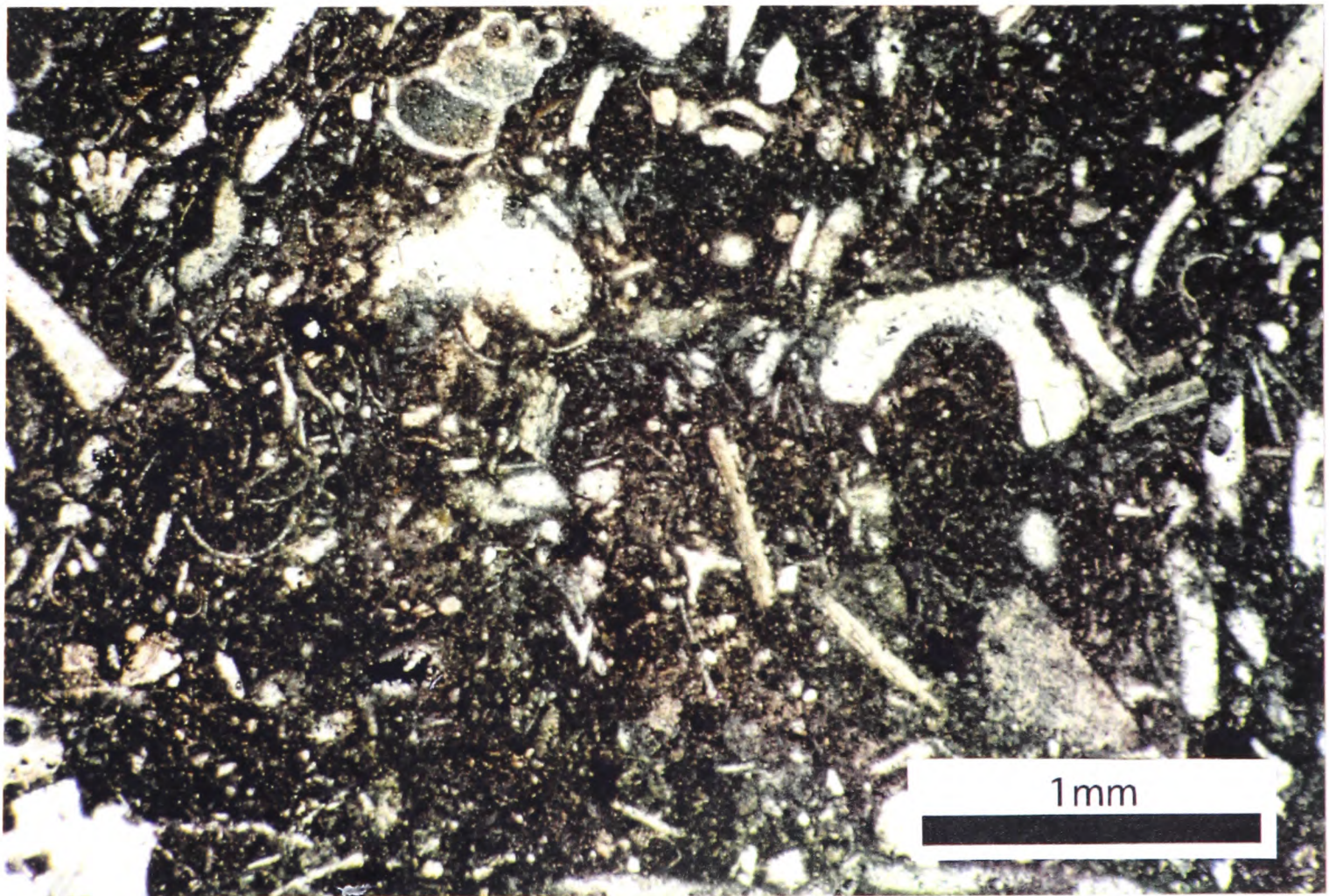


Figure 6.10b Photomicrograph of facies 3, bioclastic packstone

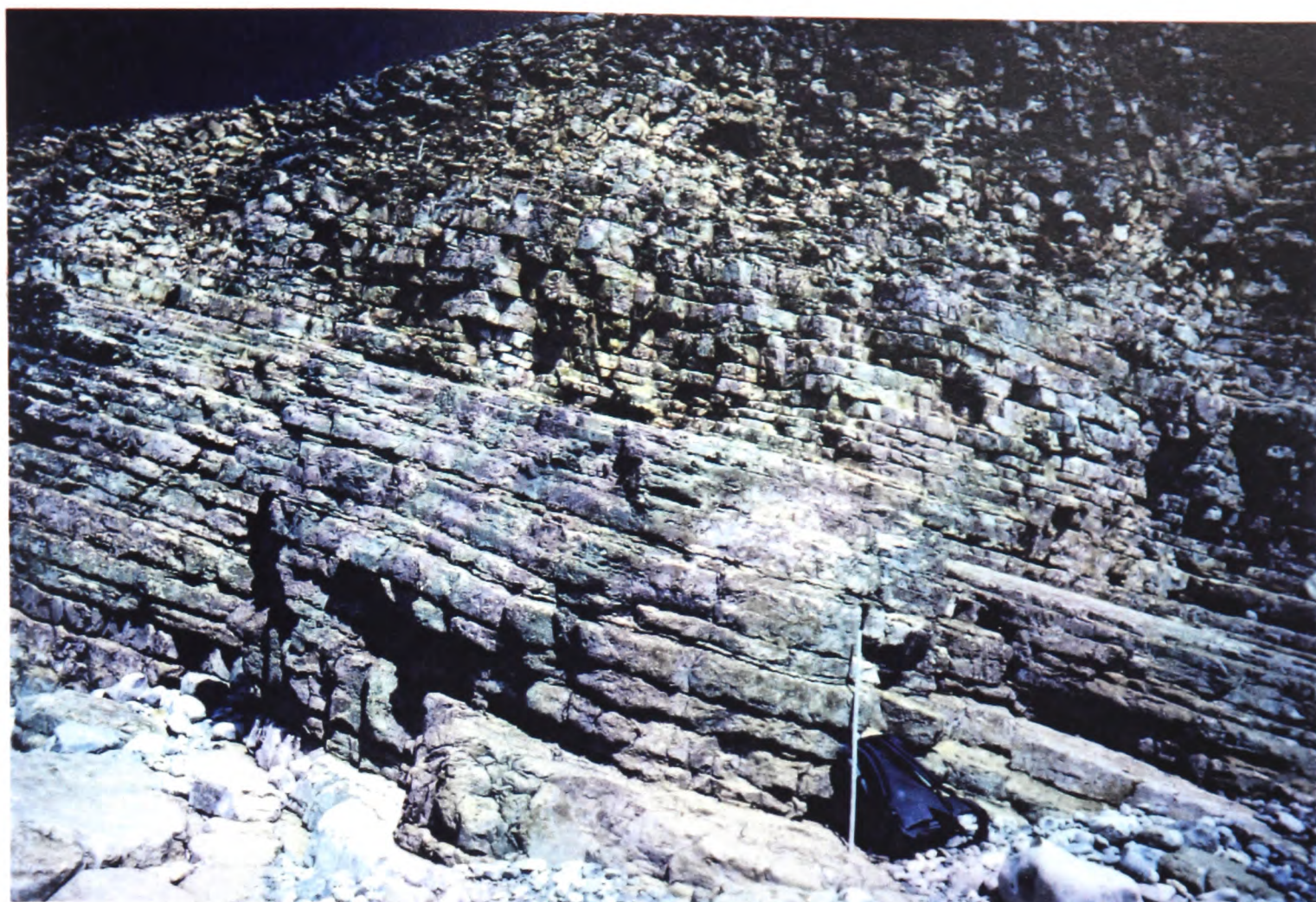


Figure 6.11a General aspect of Brenha Formation, Unit B

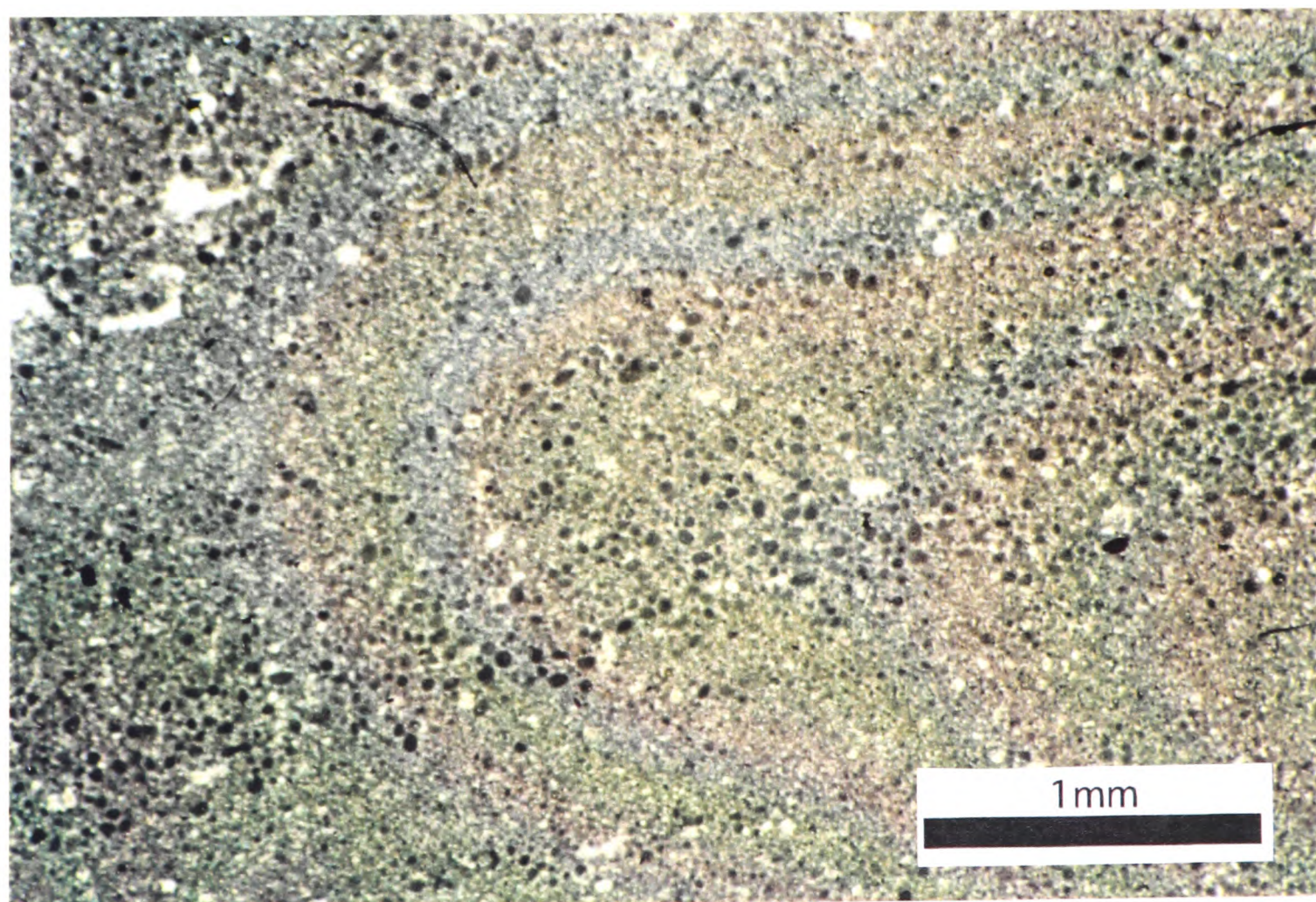


Figure 6.11b Fine-grained peloids defining cross-lamination in Unit B

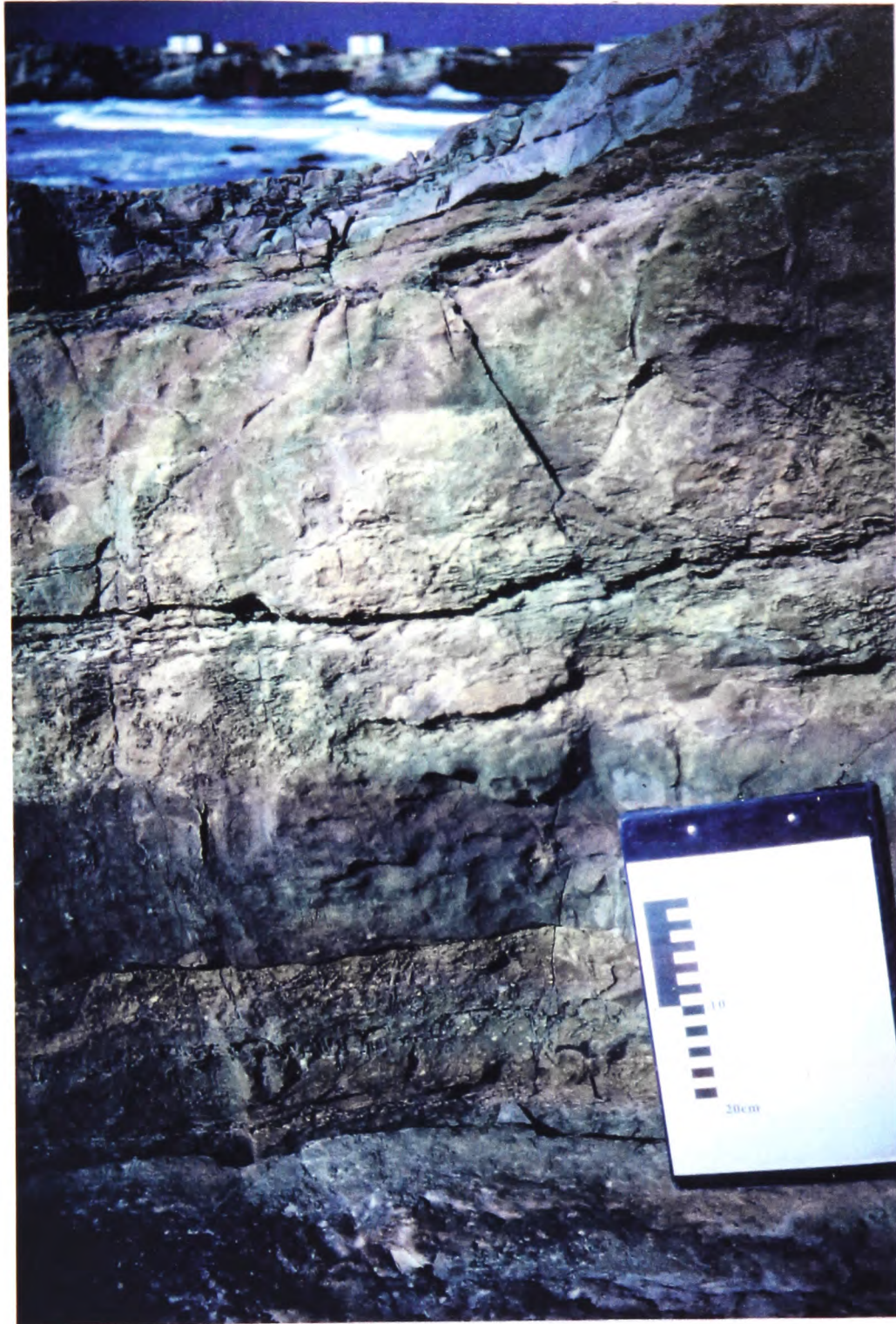


Figure 6.12 Typical chert bed from Unit B. Note sharp, undulating base and transitional top

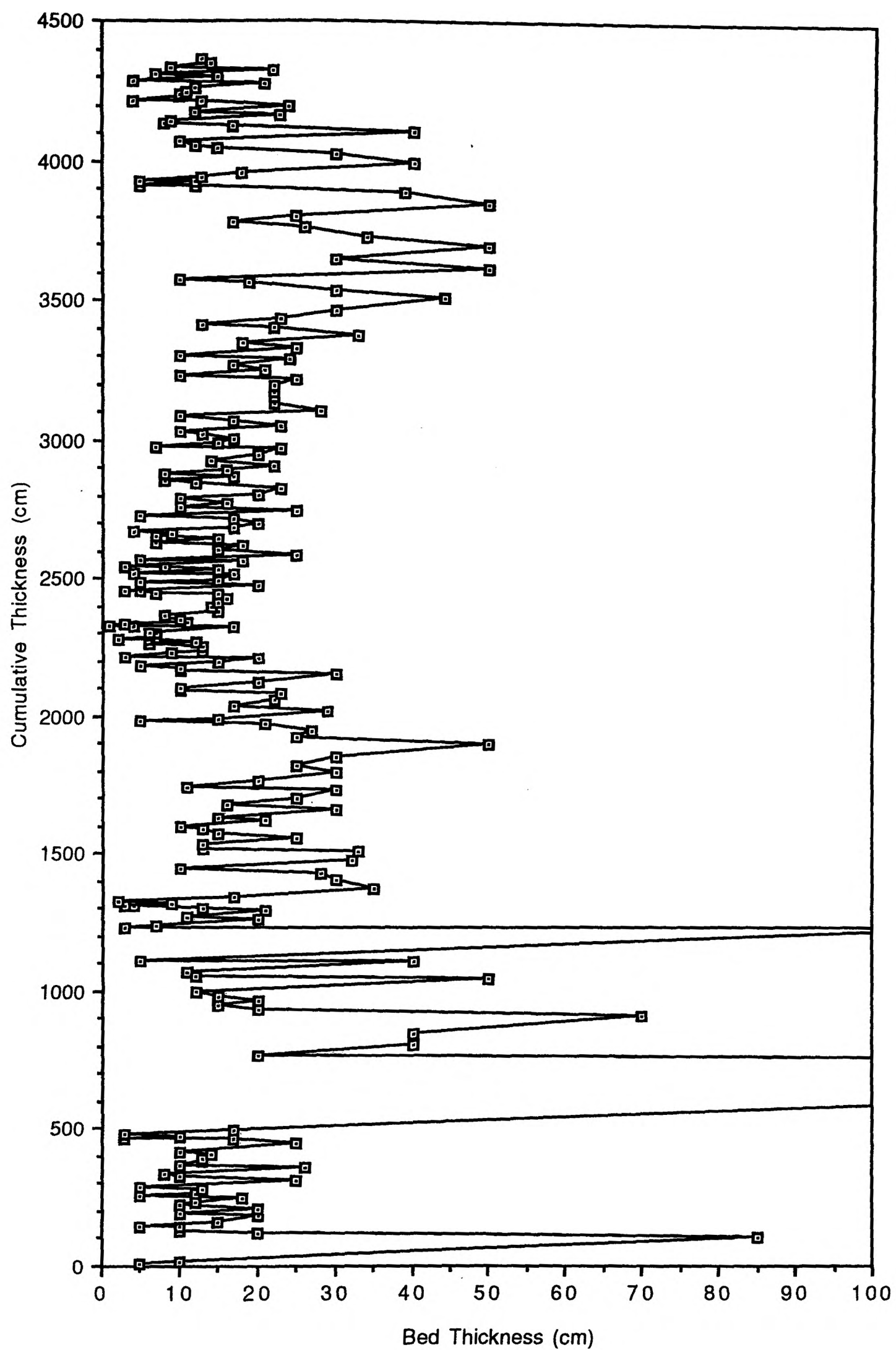


Figure 6.13 Bed Thickness Graph for Brenha Fm., Unit B, Peniche



Figure 6.14a General aspect of Brenha formation, Unit C

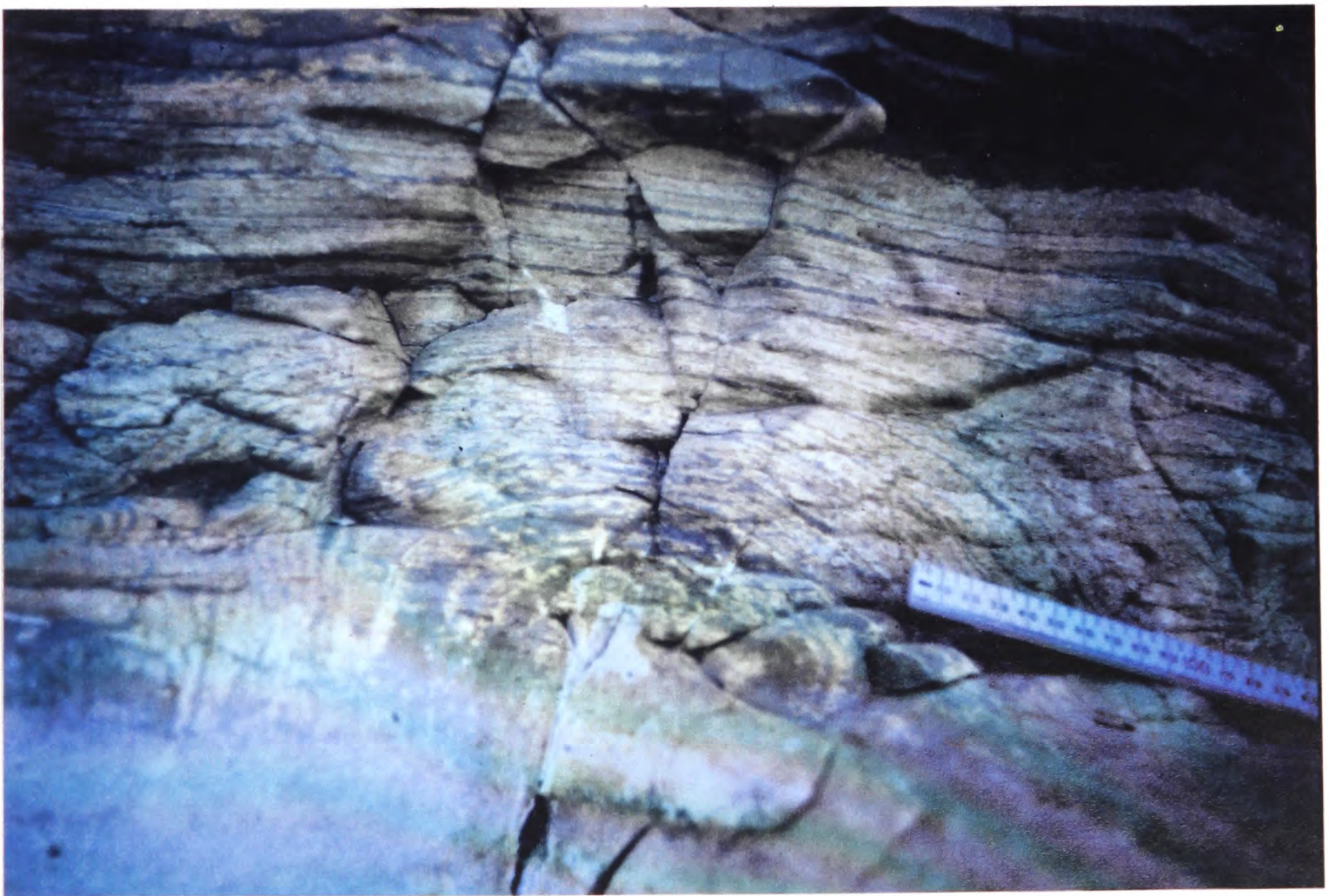


Figure 6.14b Detail of pseudo-stromatolitic lamination, Unit C

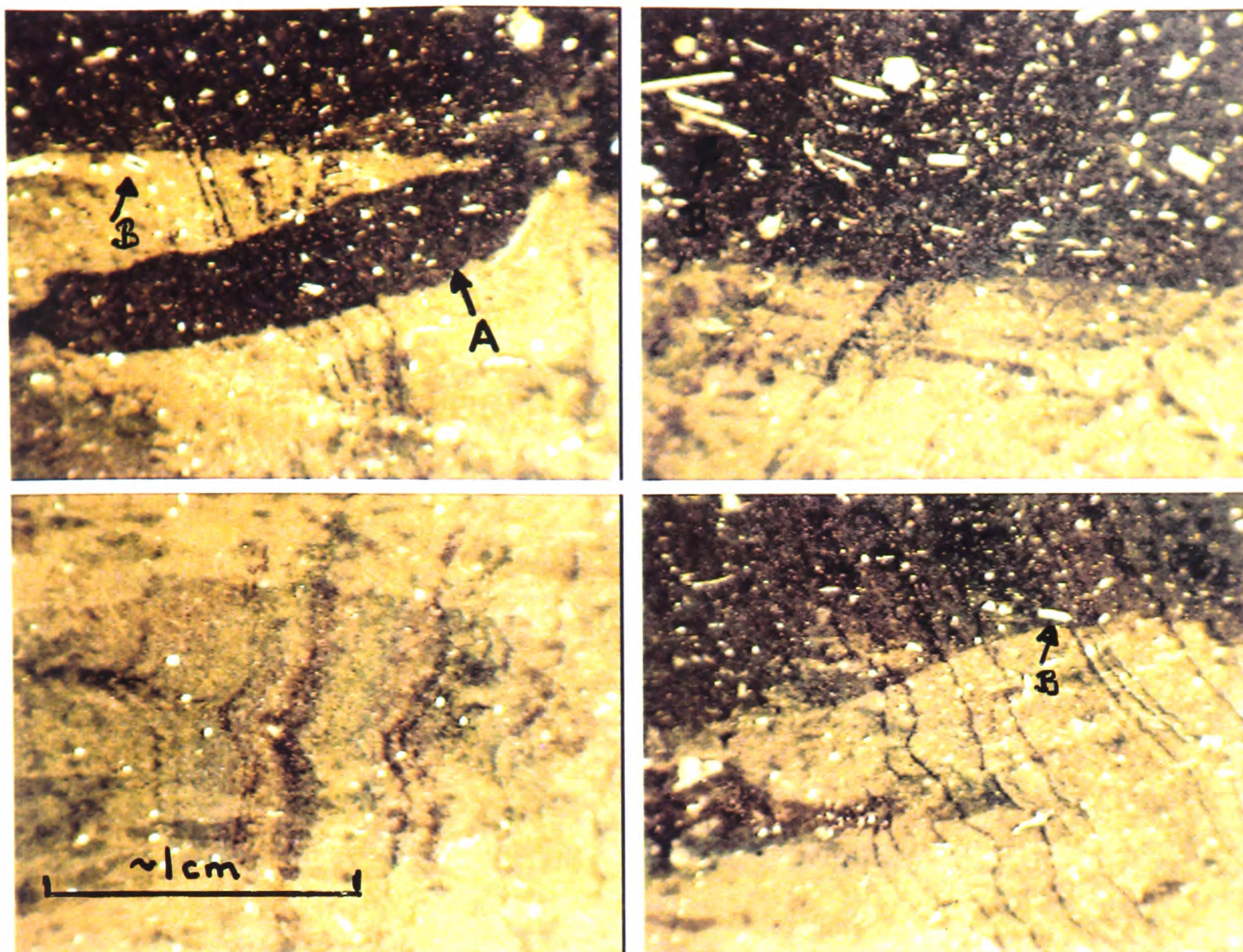


Figure 6.15a Photomicrograph of sediment peels from Unit C showing lamination cross-cutting sediment fabric, including burrow (A) and shell fragments (B)



Figure 6.15b Detail of lamination showing close association with fracturing and weathering patterns in the limestones



Figure 6.16a General aspect of the lower part of Unit D



Figure 6.16b Detail of Unit D showing granular texture of some limestones and adjacent marls

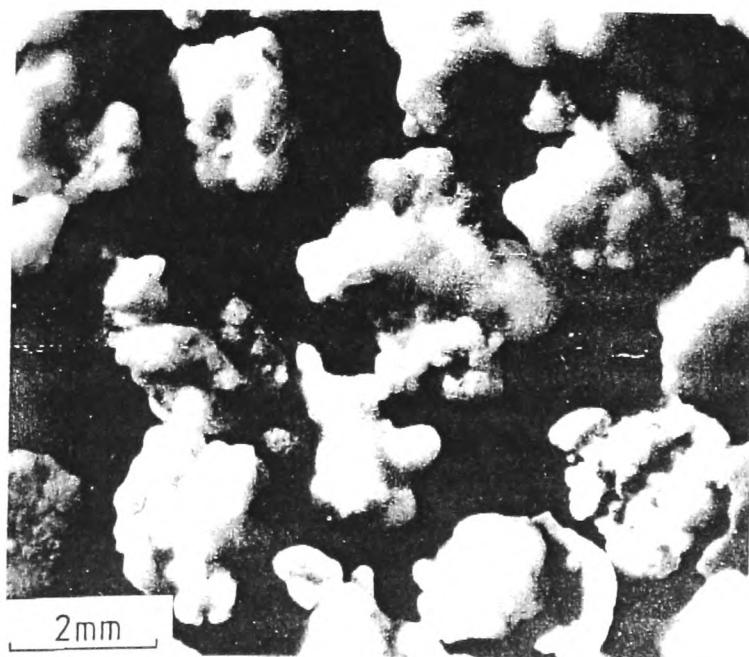


Figure 6.17 Comparison of granules in Unit D (above) with modern grapestones from the Bahamas (below, photographed by Roger Till and illustrated in Tucker & Wright, 1990)

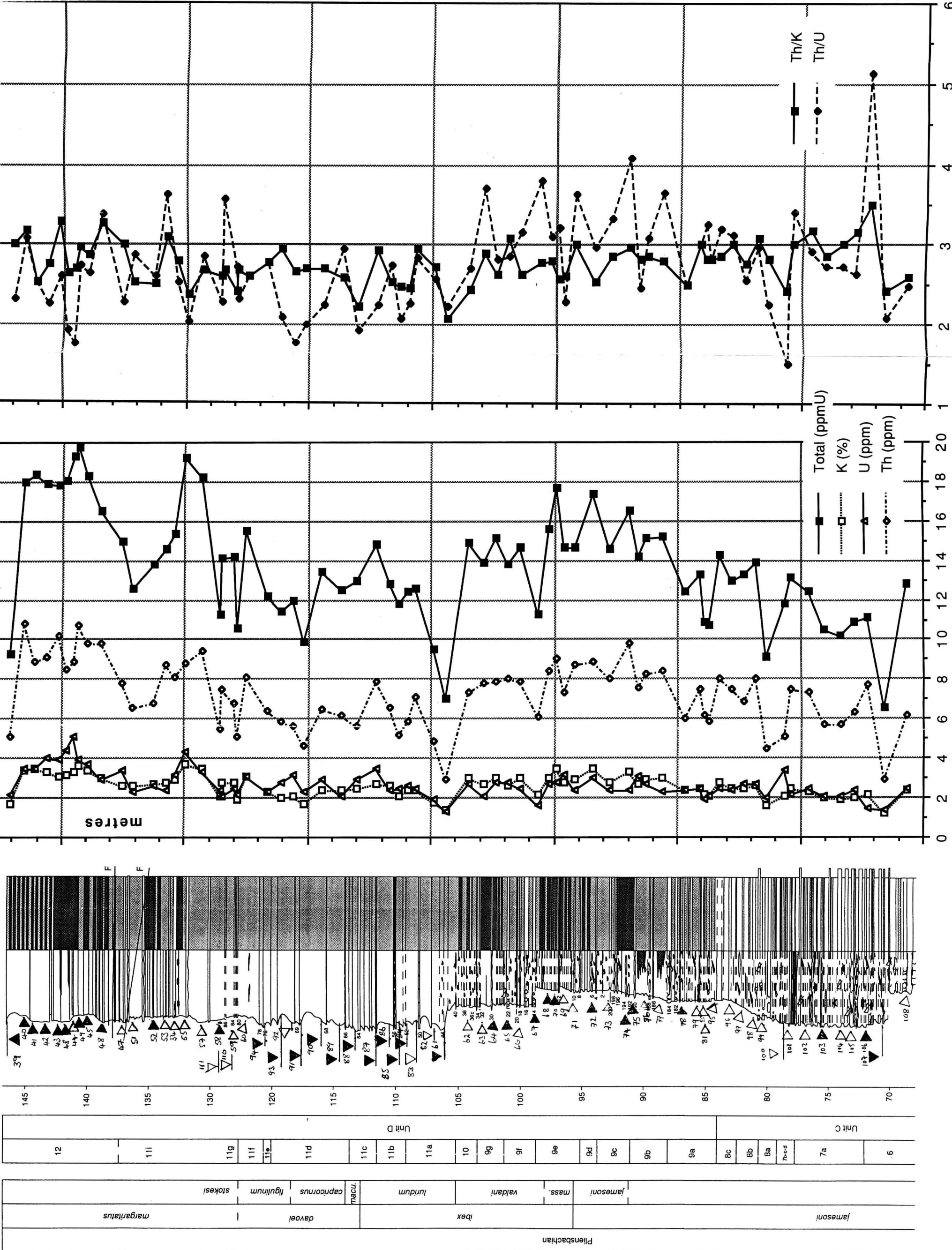


Figure 6.18 Units C-D: spectral gamma-ray data; see Appendix 1 for symbols used to describe gamma-ray measurement stations and for tabulated data.

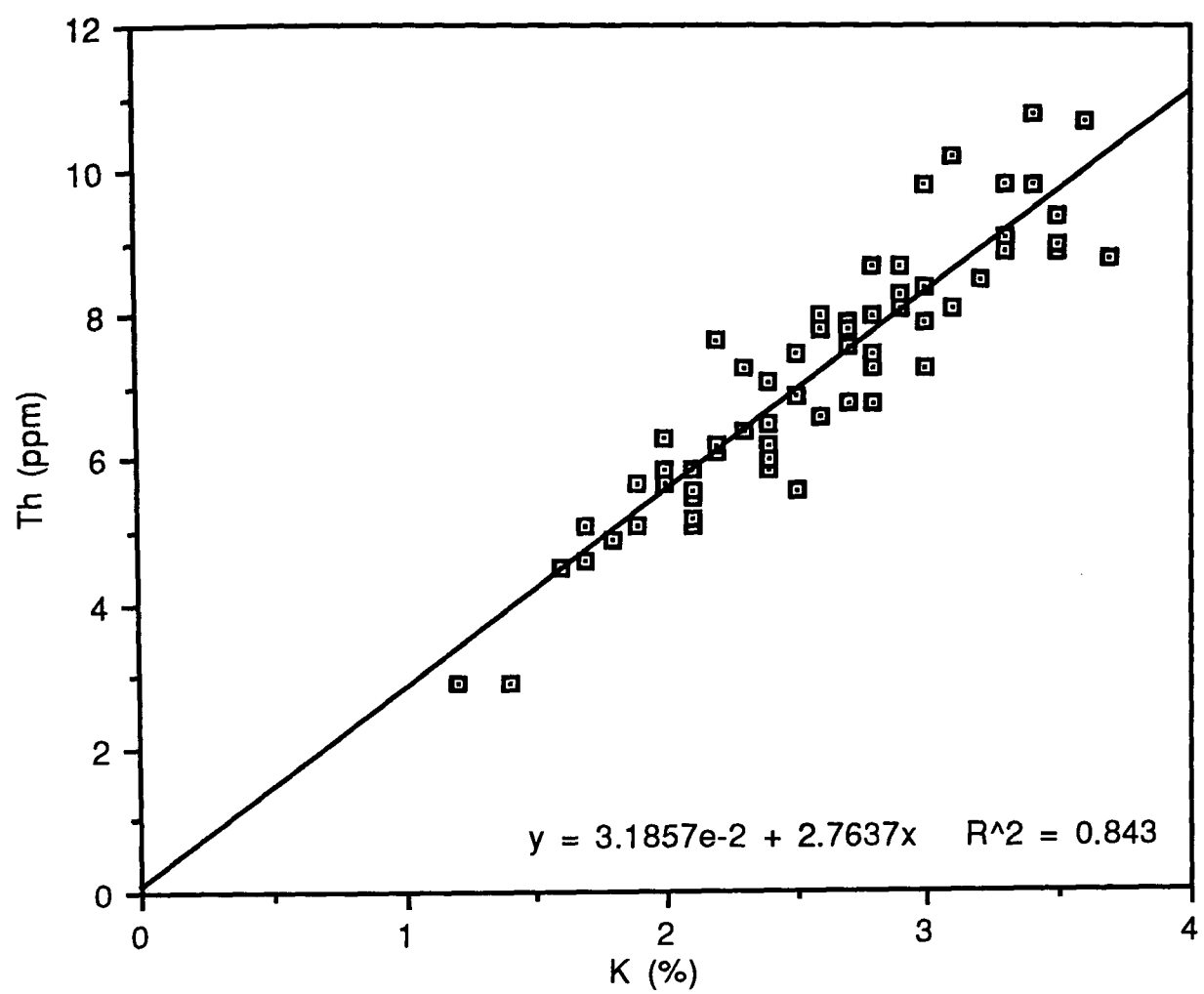


Figure 6.19a Thorium v. Potassium for Unit D, Peniche

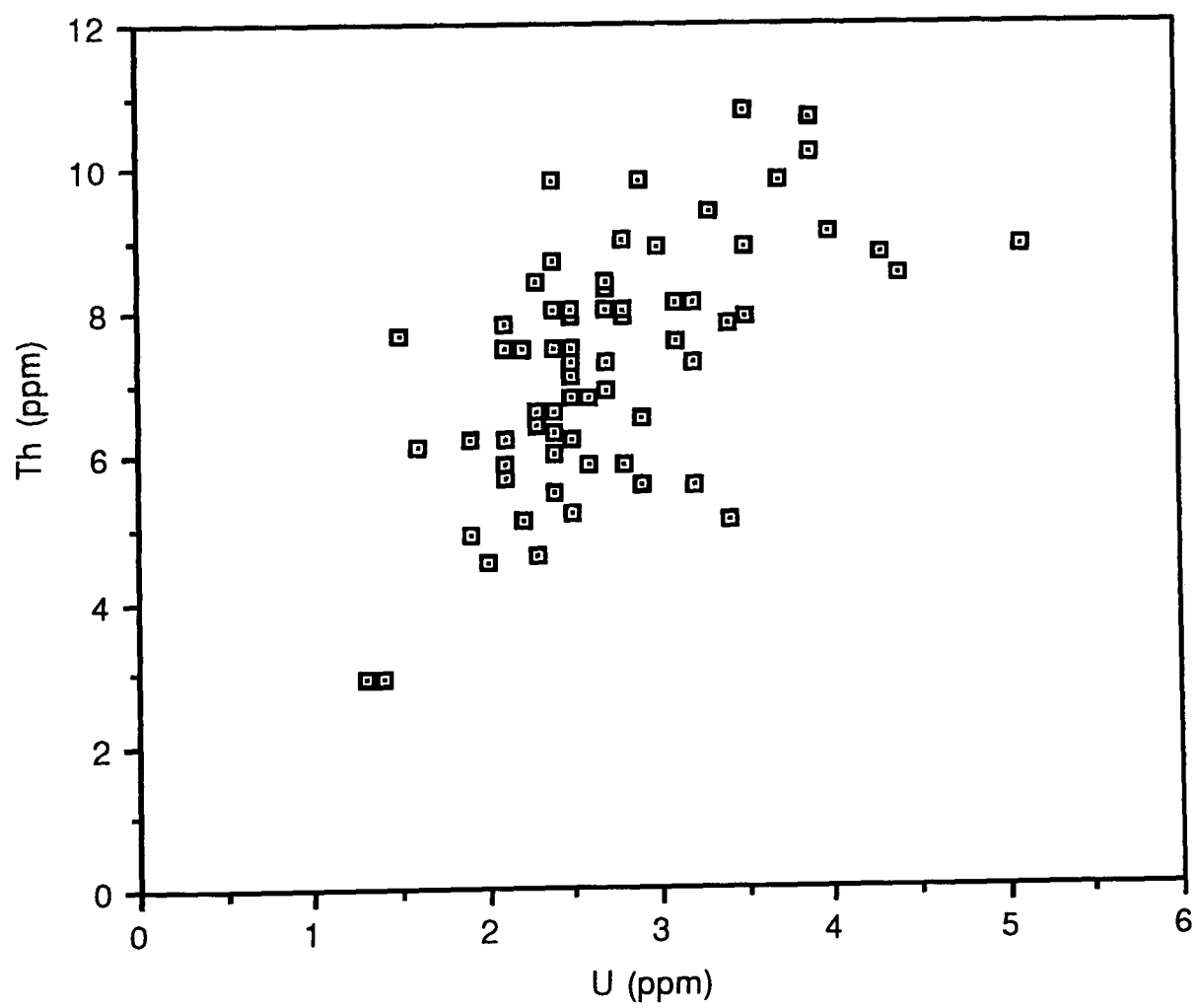


Figure 6.19b Thorium v. Uranium for Unit D, Peniche



Figure 6.20a Light and dark marl alternations at the top of Unit D passing sharply upwards into Unit E limestones (at arrow)



Figure 6.20b General aspect of Unit E, exposed in cliffs along the western side of Portinho da Areia do Norte

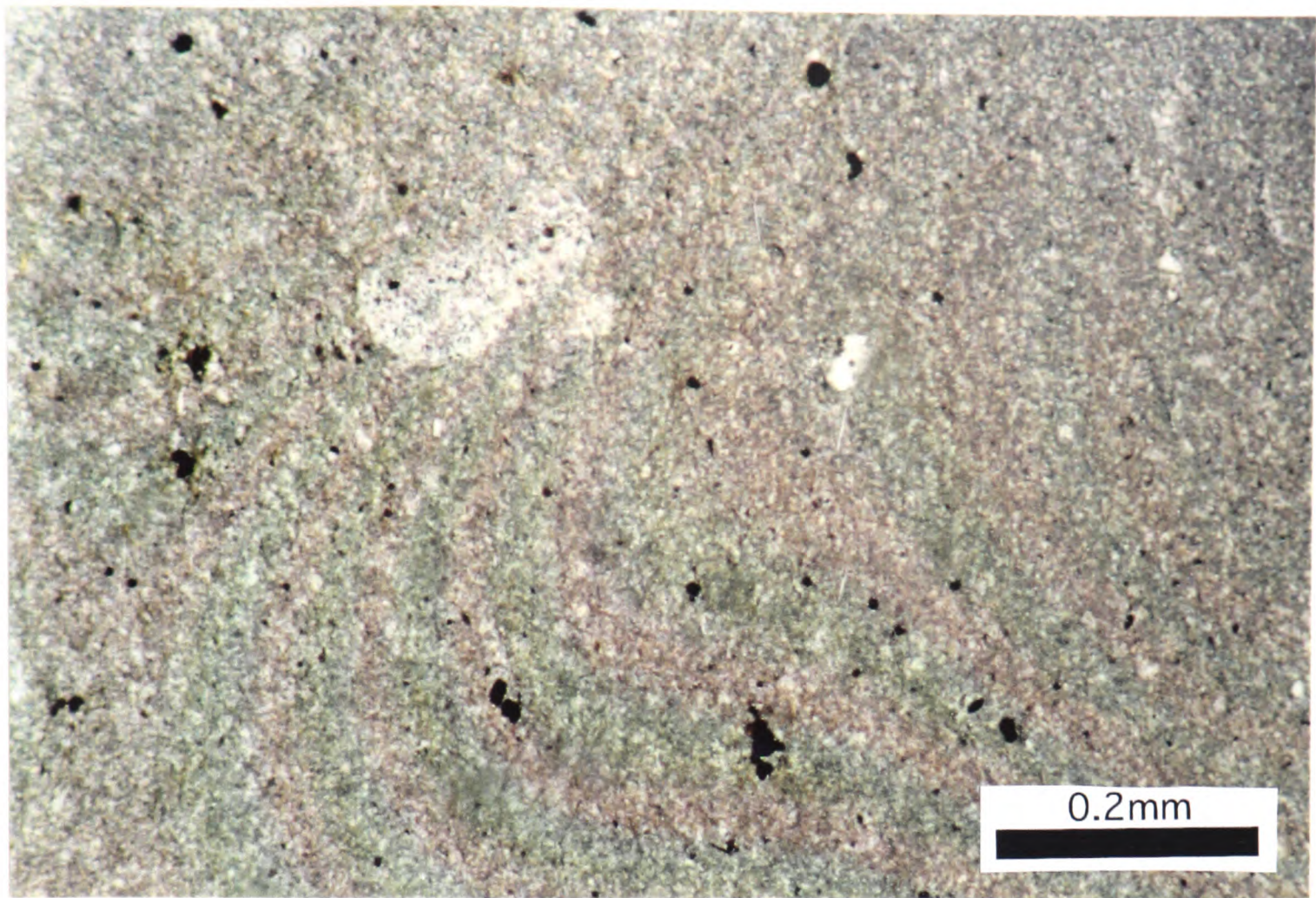


Figure 6.21a Photomicrograph of lime mudstone facies, Unit E

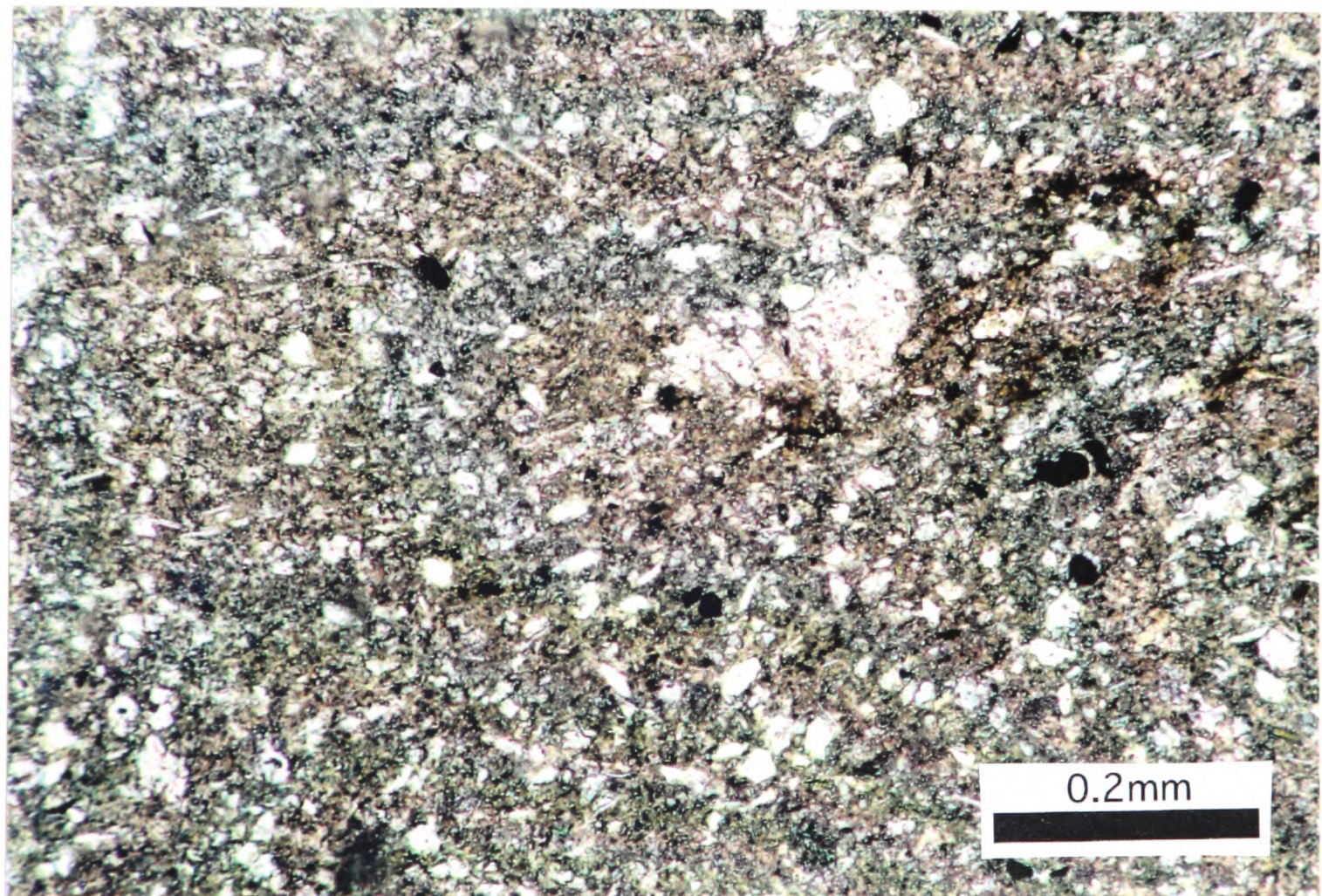


Figure 6.21b Photomicrograph of argillaceous wackestone facies, Unit E

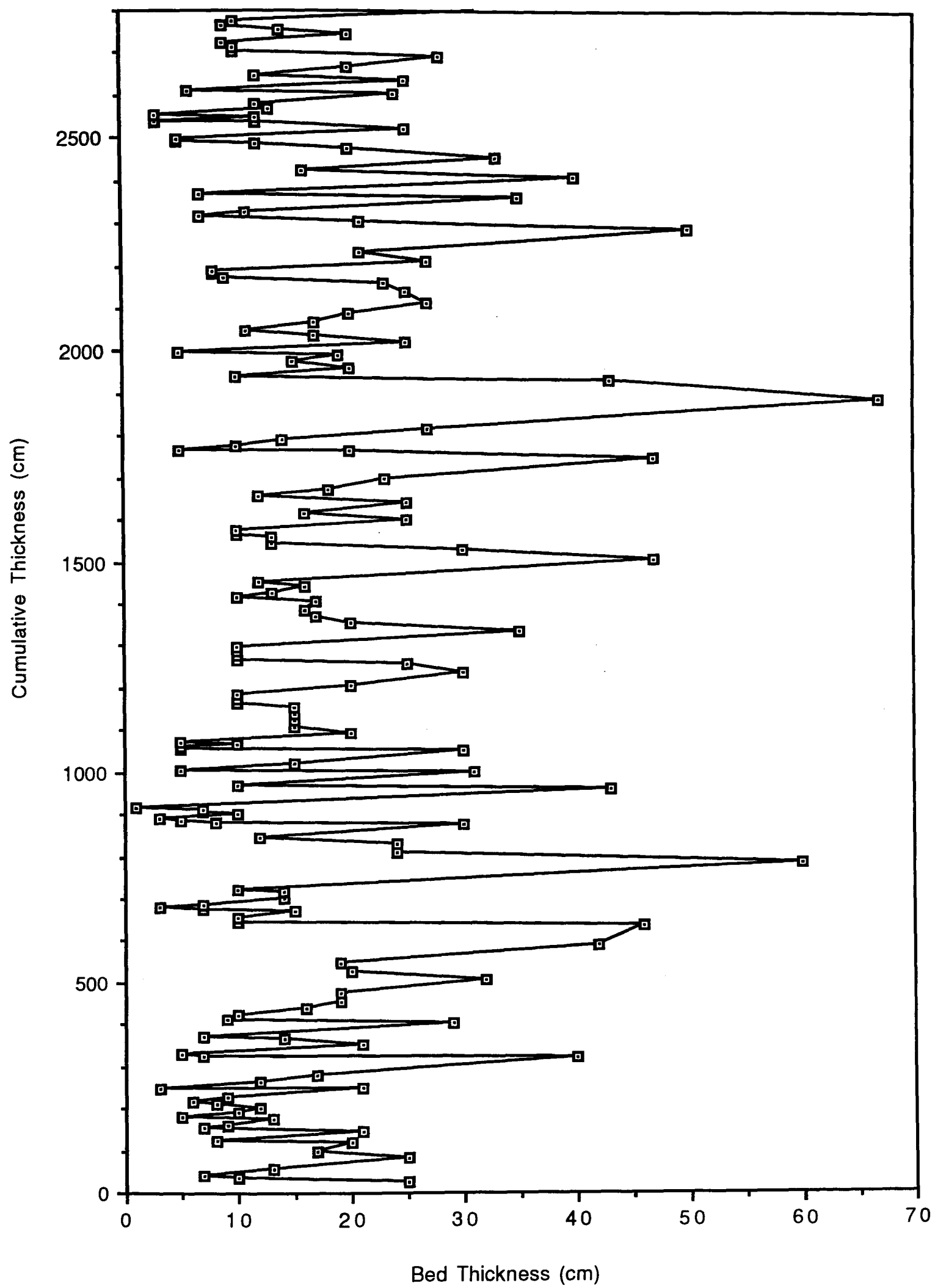


Figure 6.22 Bed Thickness Graph for Brenha Fm., Unit E, Peniche



Figure 6.23a Foreground: bay formed in Unit F marls, the top of the Unit E limestones is arrowed. Background: Portinha da Areia do Norte with Papoa peninsula indicated



Figure 6.23b Base of Unit F, rucksack is on Unit E limestones

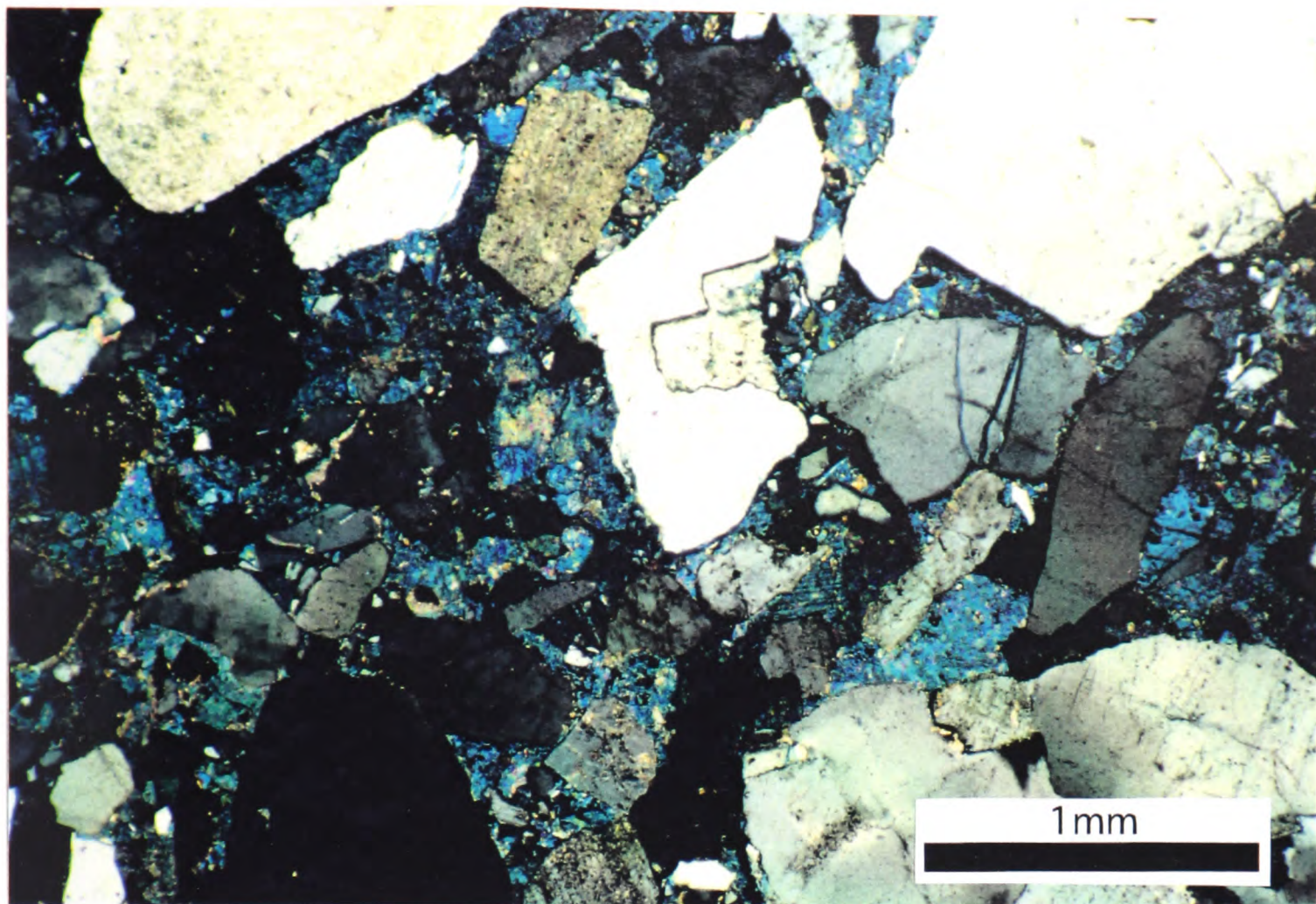


Figure 6.24a Photomicrograph (xpl) of coarse sandstone from Unit F. Carbonate matrix stained blue



Figure 6.24b Convex-up sandbody, Unit F (approx. 207m on log, fig. 6.7)

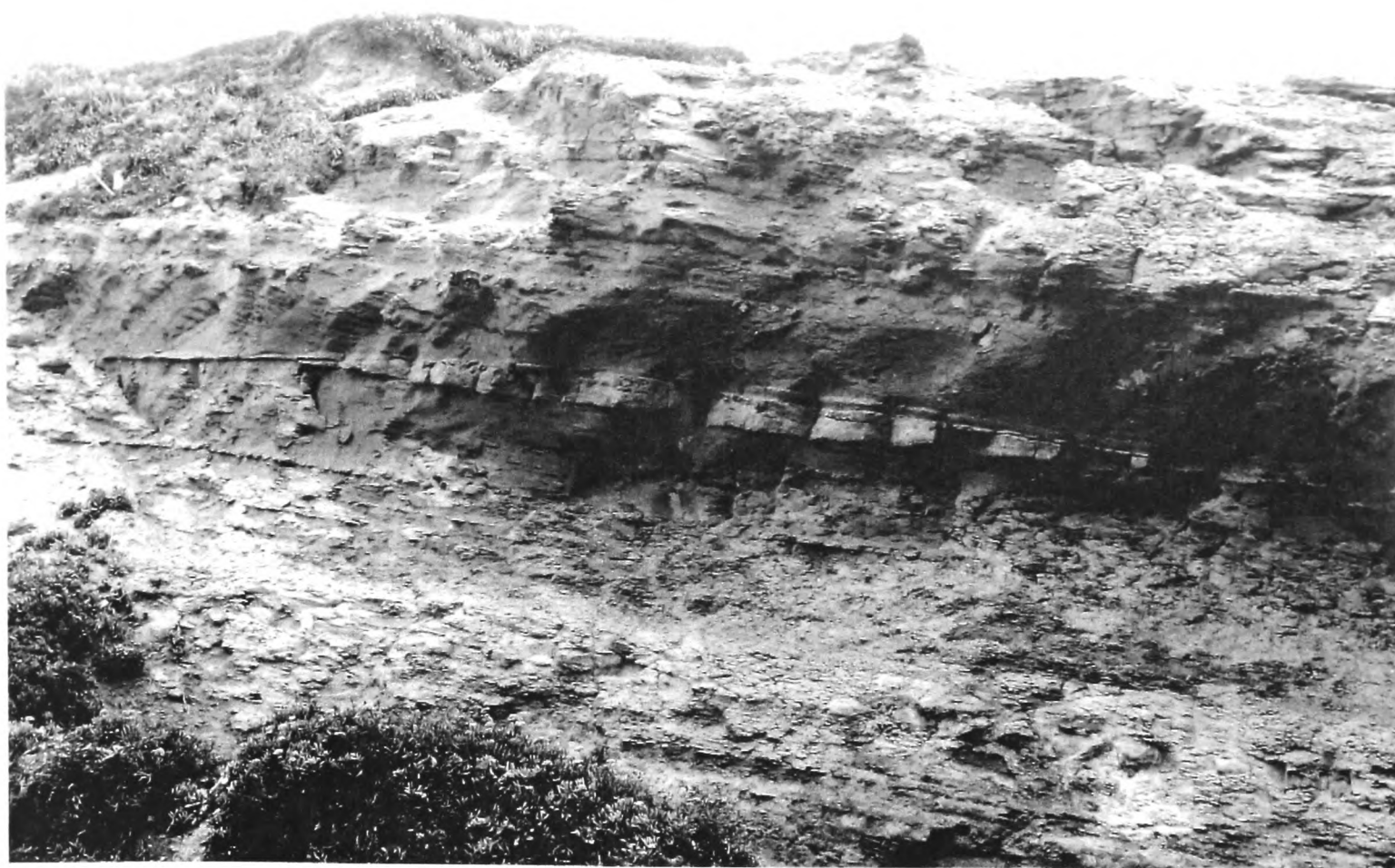
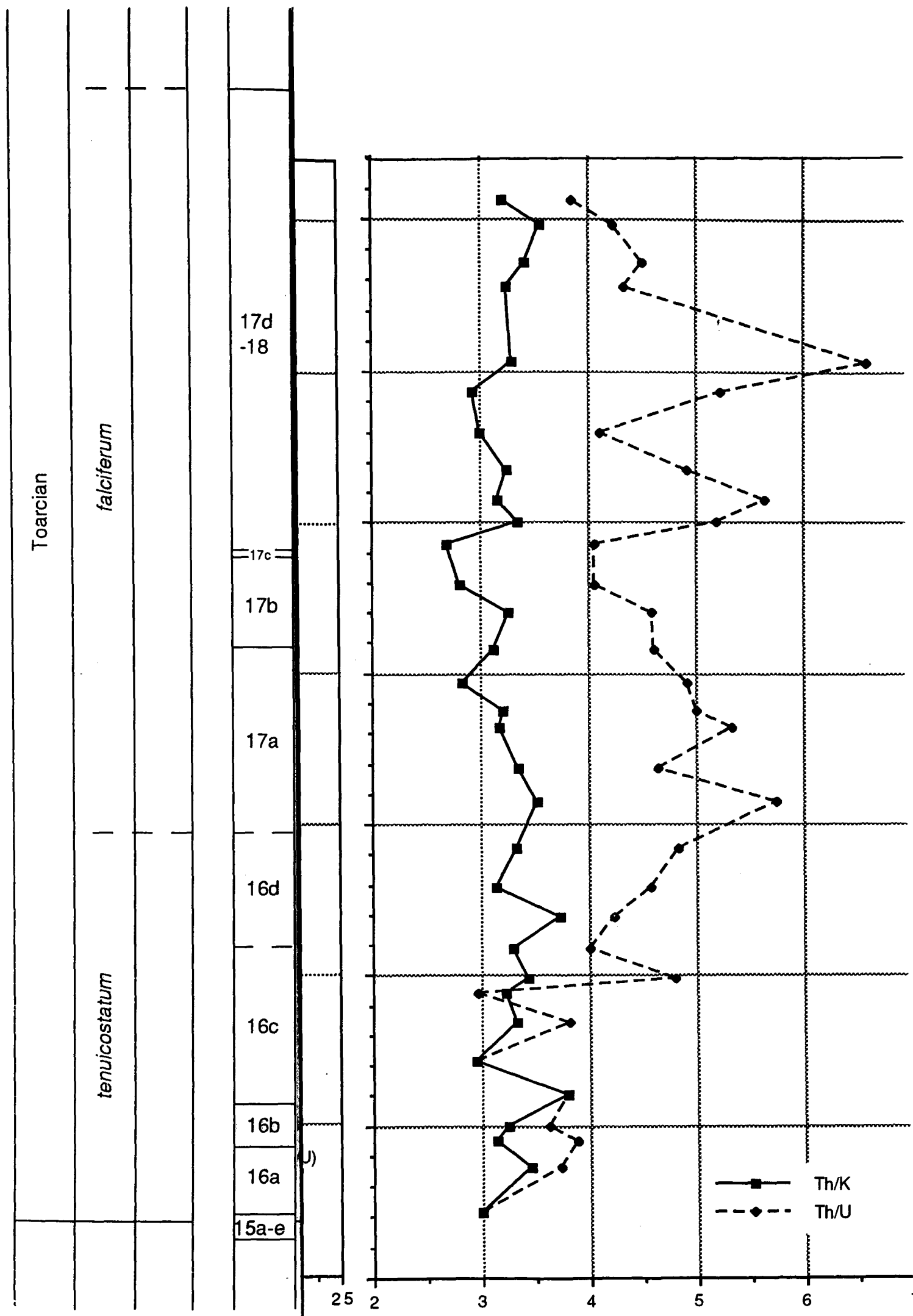


Figure 6.25a Convex-up sandbody, Unit F (approx 187m on log, fig. 6.7)



Figure 6.25b Detail immediately above sand body illustrated in 6.25a, showing very coarse clasts "frozen" in matrix



Th-ray measurement

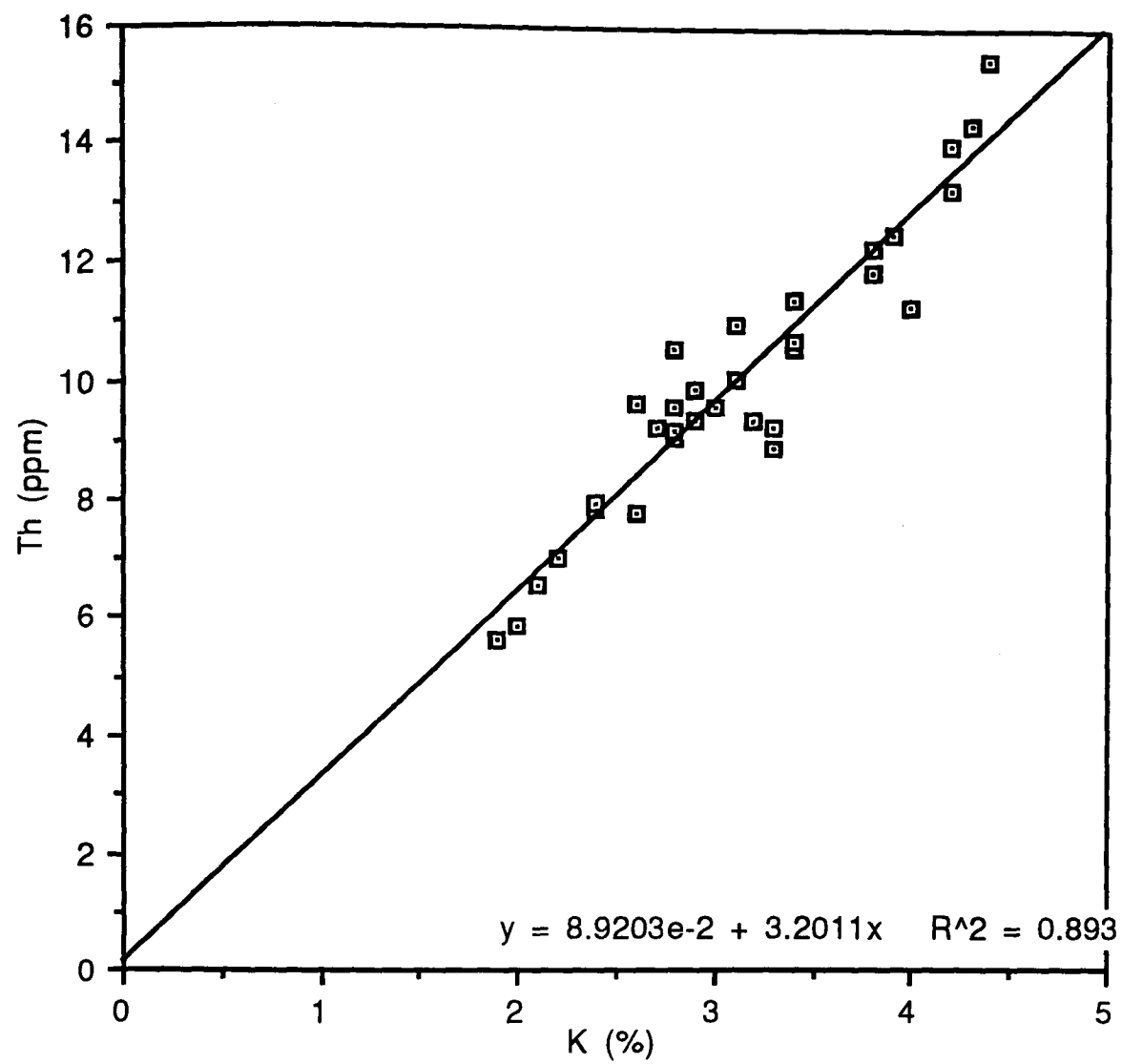


Figure 6.27a Thorium v. Potassium for Unit F, Peniche

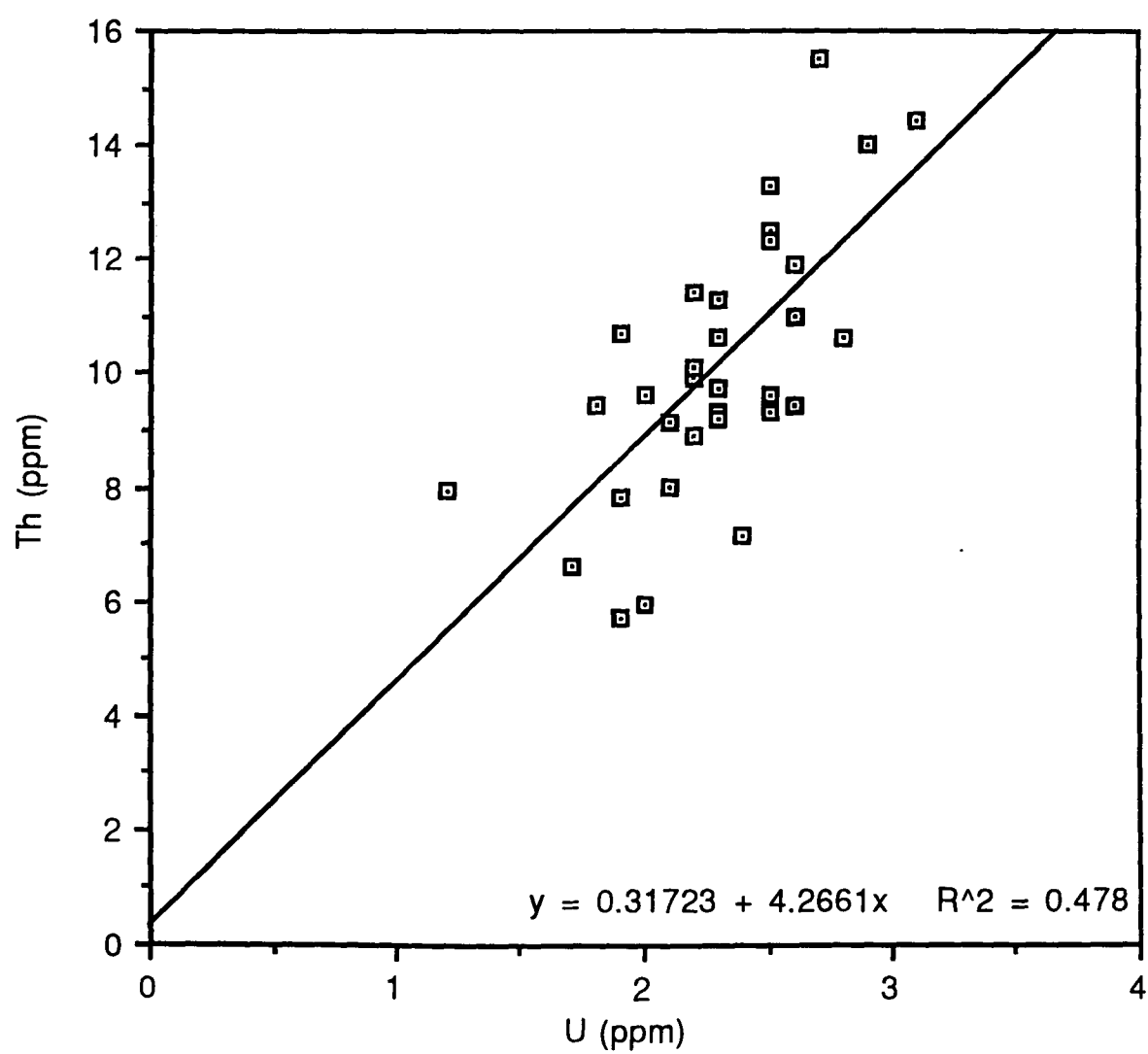


Figure 6.27b Thorium v. Uranium for Unit F, Peniche

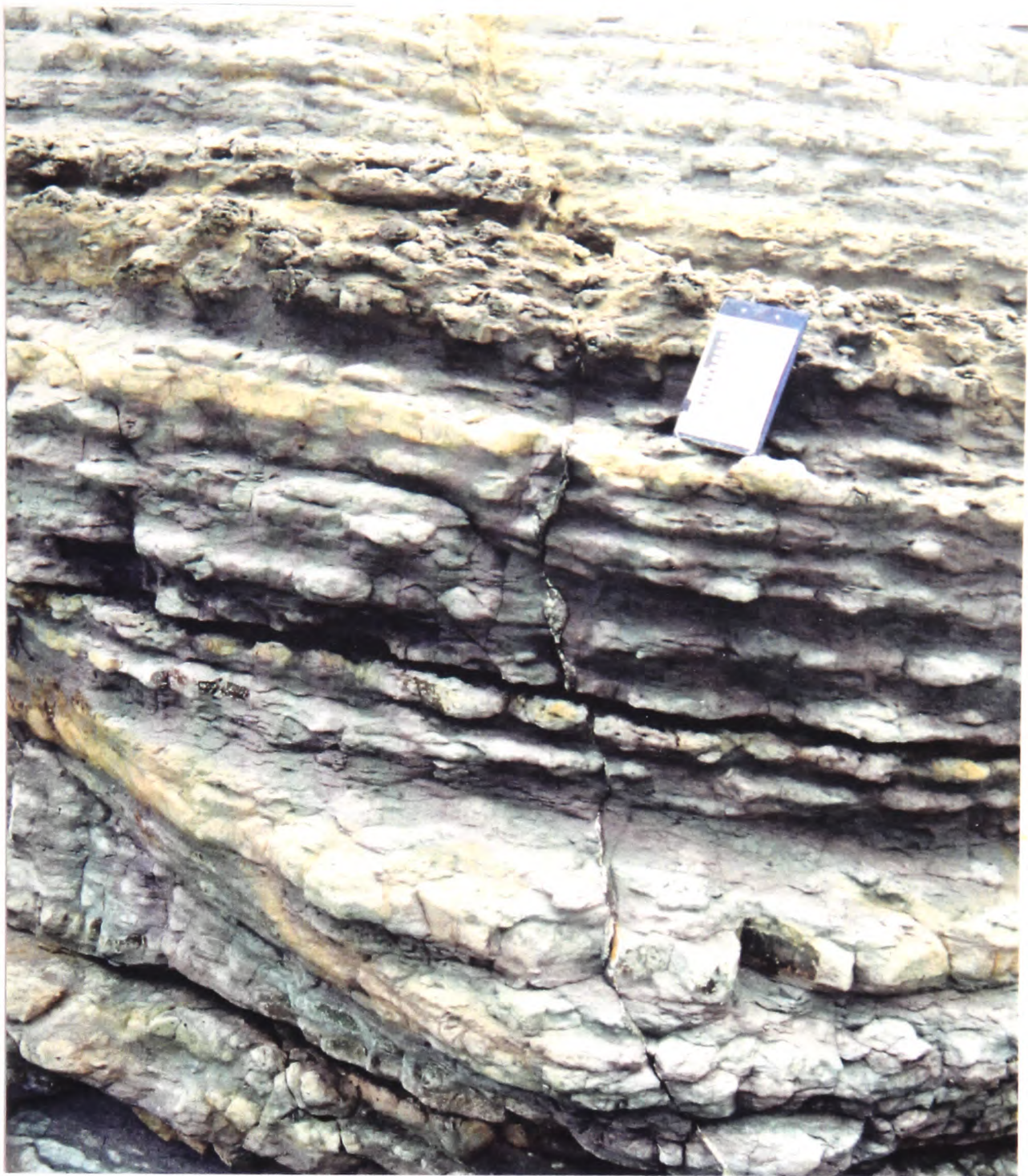


Figure 6.28a Nodular limestone-marl alternations typical of Unit G

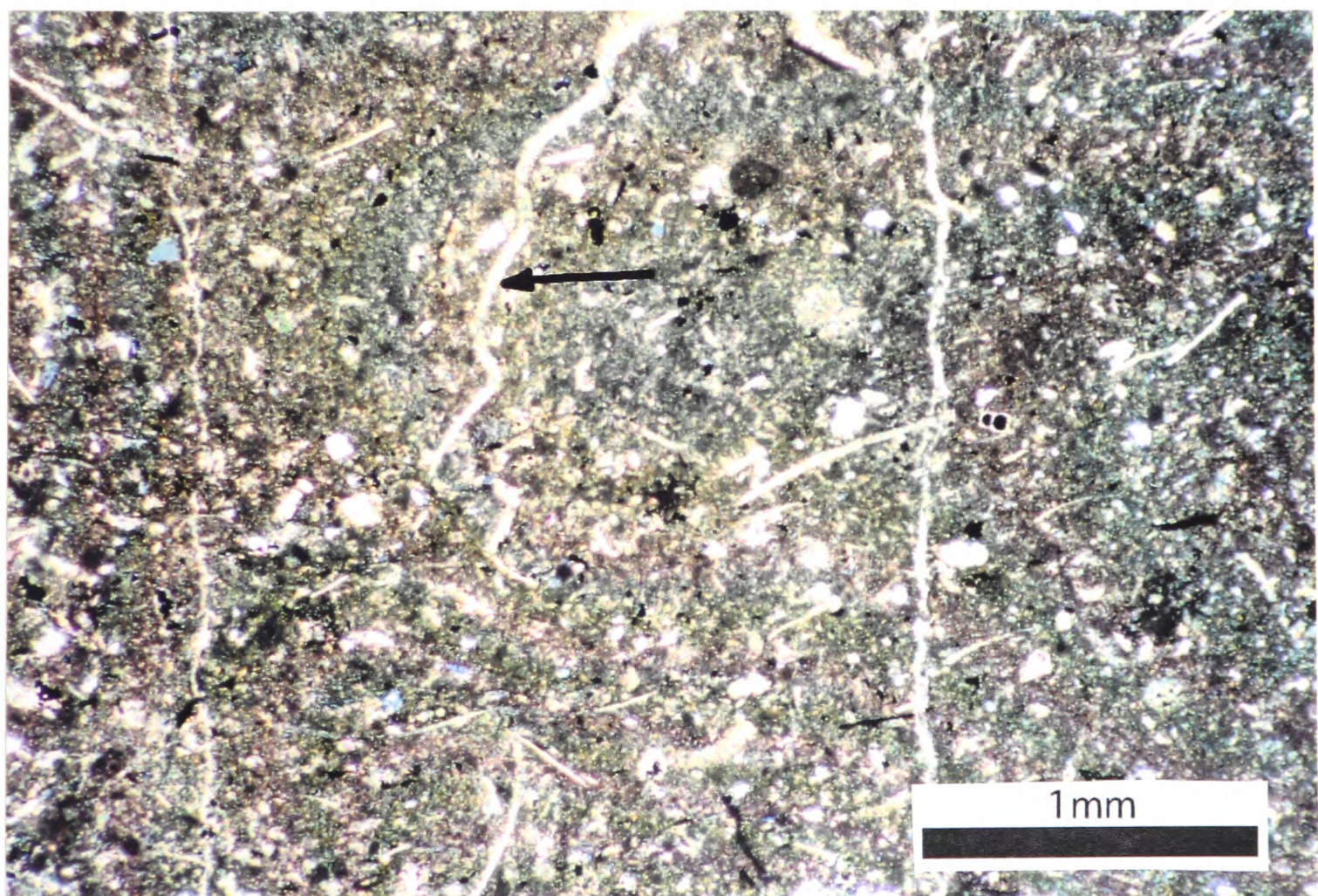


Figure 6.28b Photomicrograph of Unit G limestone (xpl) showing filamentous bivalves (arrowed)

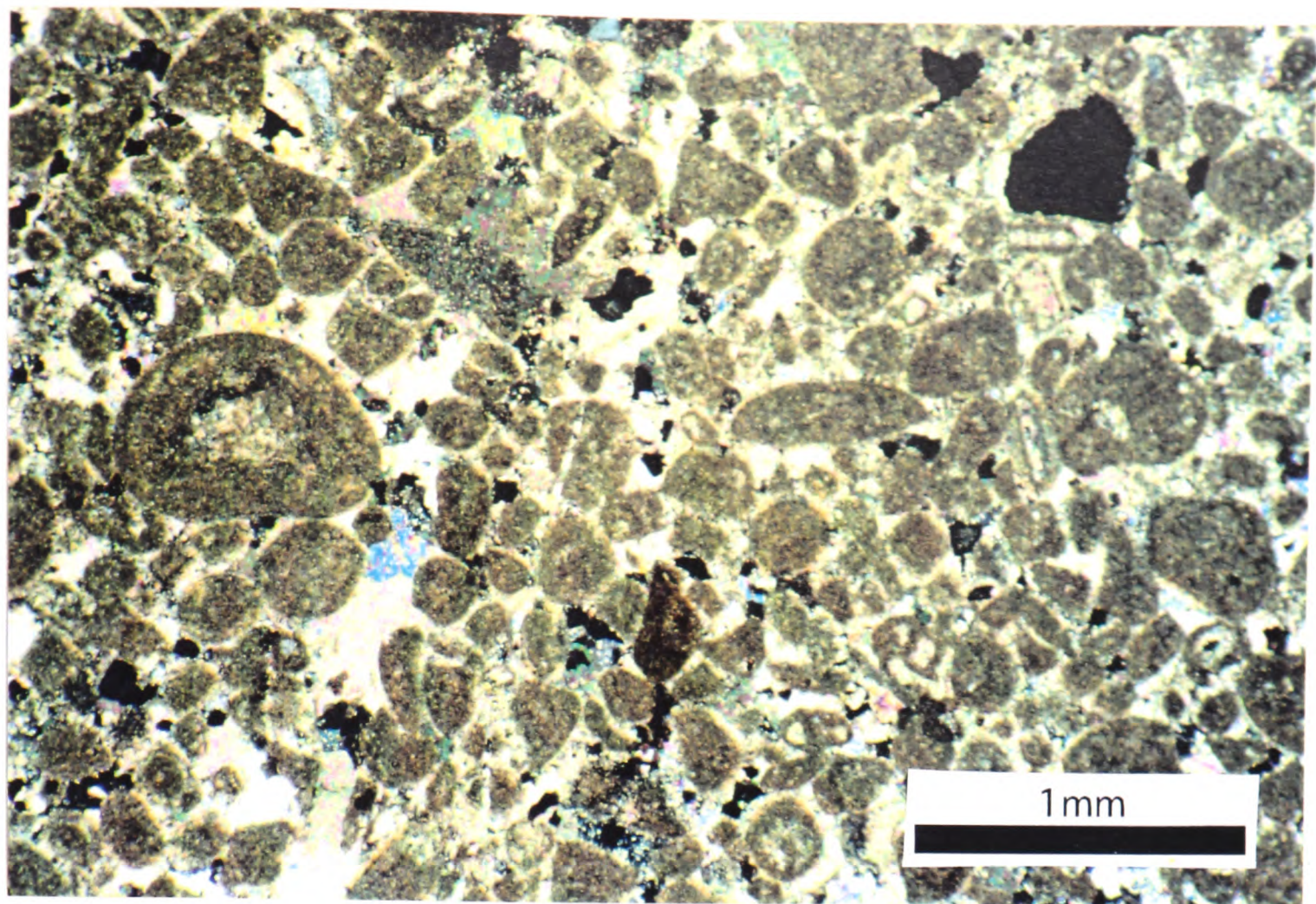


Figure 6.30a Photomicrograph of peletal grainstone from turbidite bed within Wright & Wilson's Unit 3, Peniche (sample 2PW102, xpl)

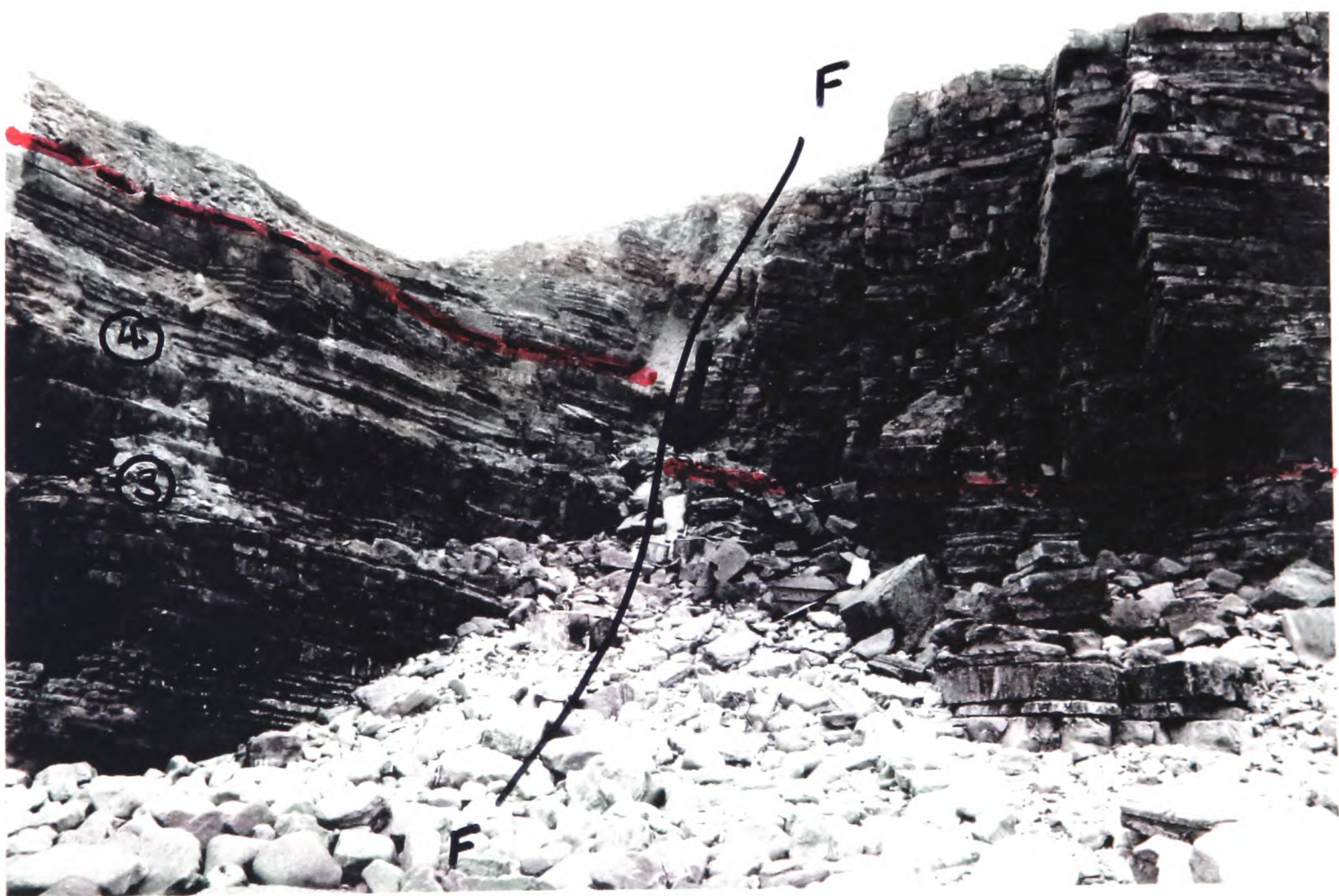


Figure 6.30b Proposed cross-fault correlation between "Unit 4" and "Unit 5", immediately east of Cerro do Cao (numbers refer to log, fig. 6.29)



Figure 6.37 Detail of cliff at Cabo Cavoeiro lighthouse. Surface "C" is marked (see log, fig. 6.29) and base of channel, floored by coarse siliciclastics is arrowed. Note large-scale trough-cross lamination to the right of the arrow.



Figure 6.38a Carreiro da Joana, south side of Peniche Peninsula, Base of siliciclastic unit arrowed.



Figure 6.38b Carreiro da Joana, detail of base of siliciclastic unit showing incorporation of limestone cobbles.

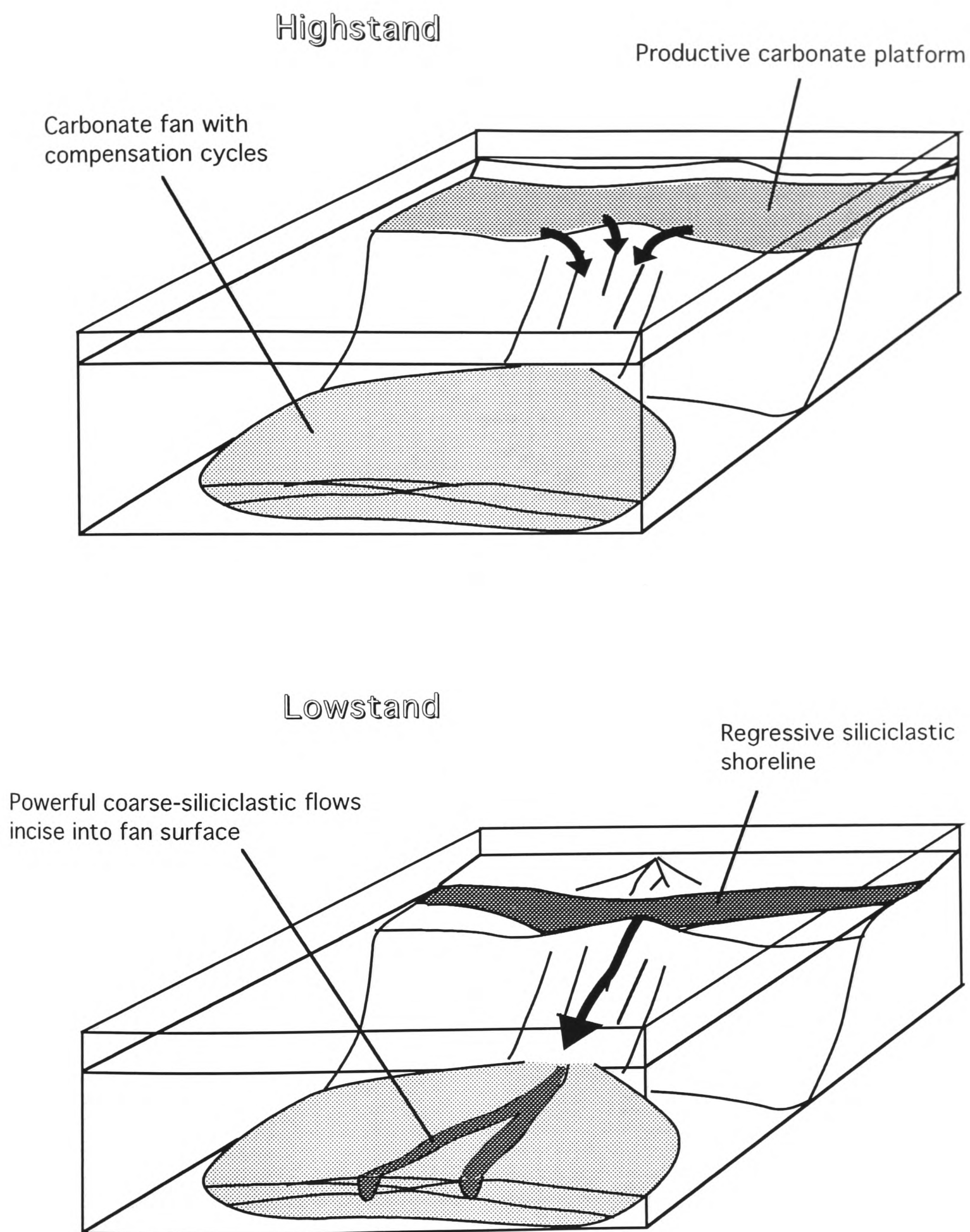


Figure 6.39 Model for mixed carbonate-clastic fan development in the Toarcian of Peniche, Portugal

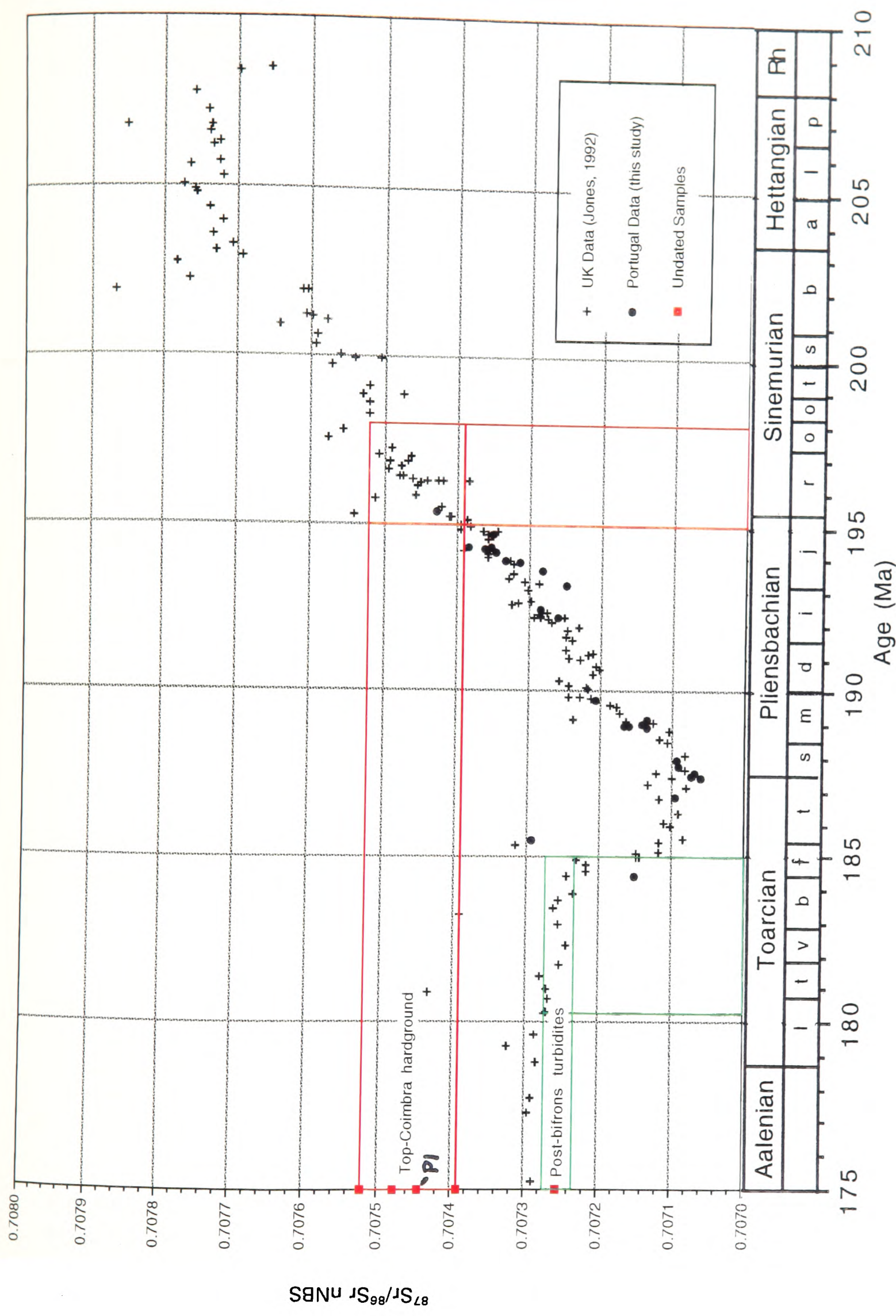


Figure 6.41 Sr-isotope values of undated samples compared with ammonite-constrained data: Peniche, Portugal

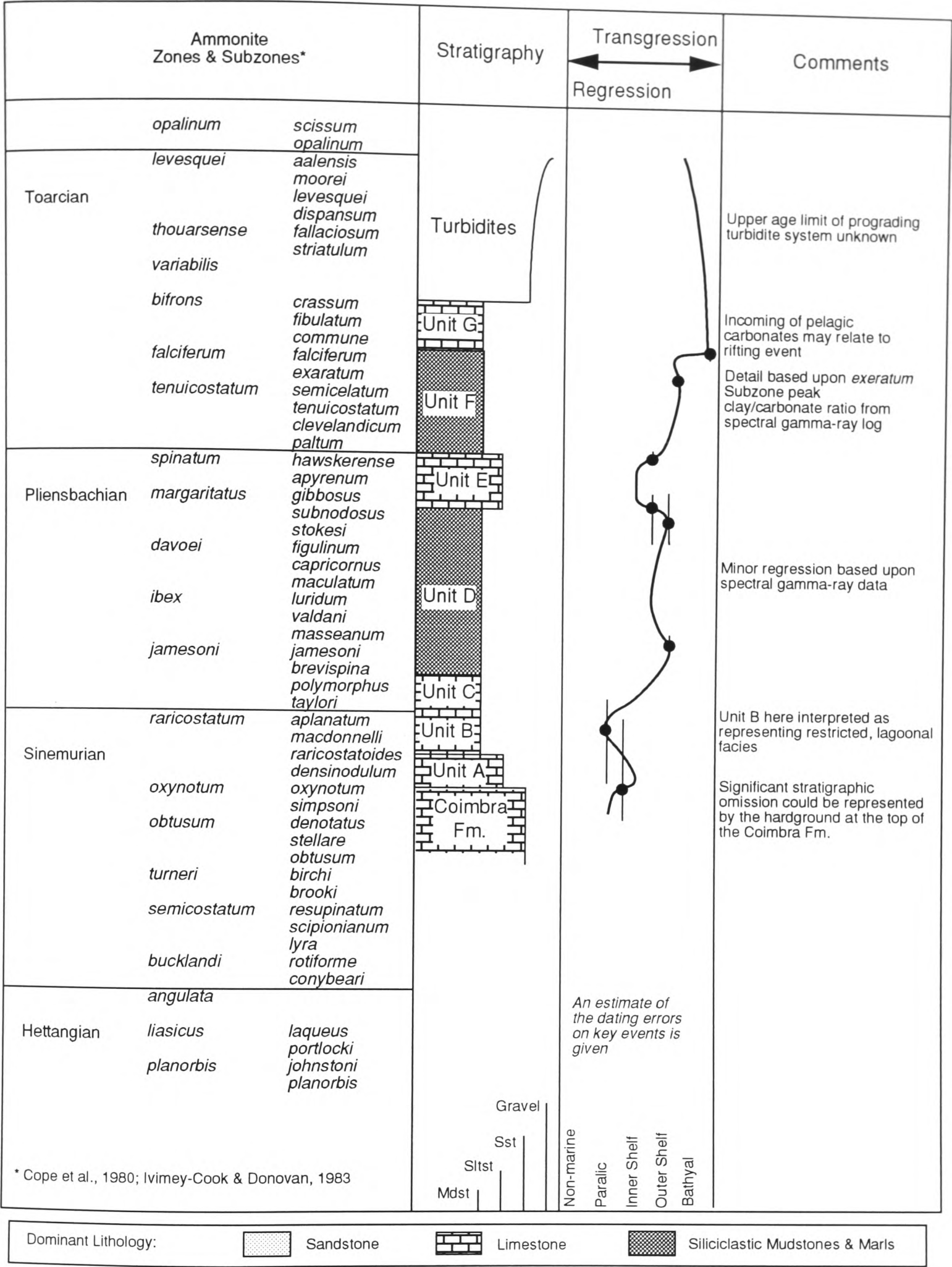


Figure 6.42 Summary of stratigraphic events in the Lower Jurassic at Peniche, Portugal

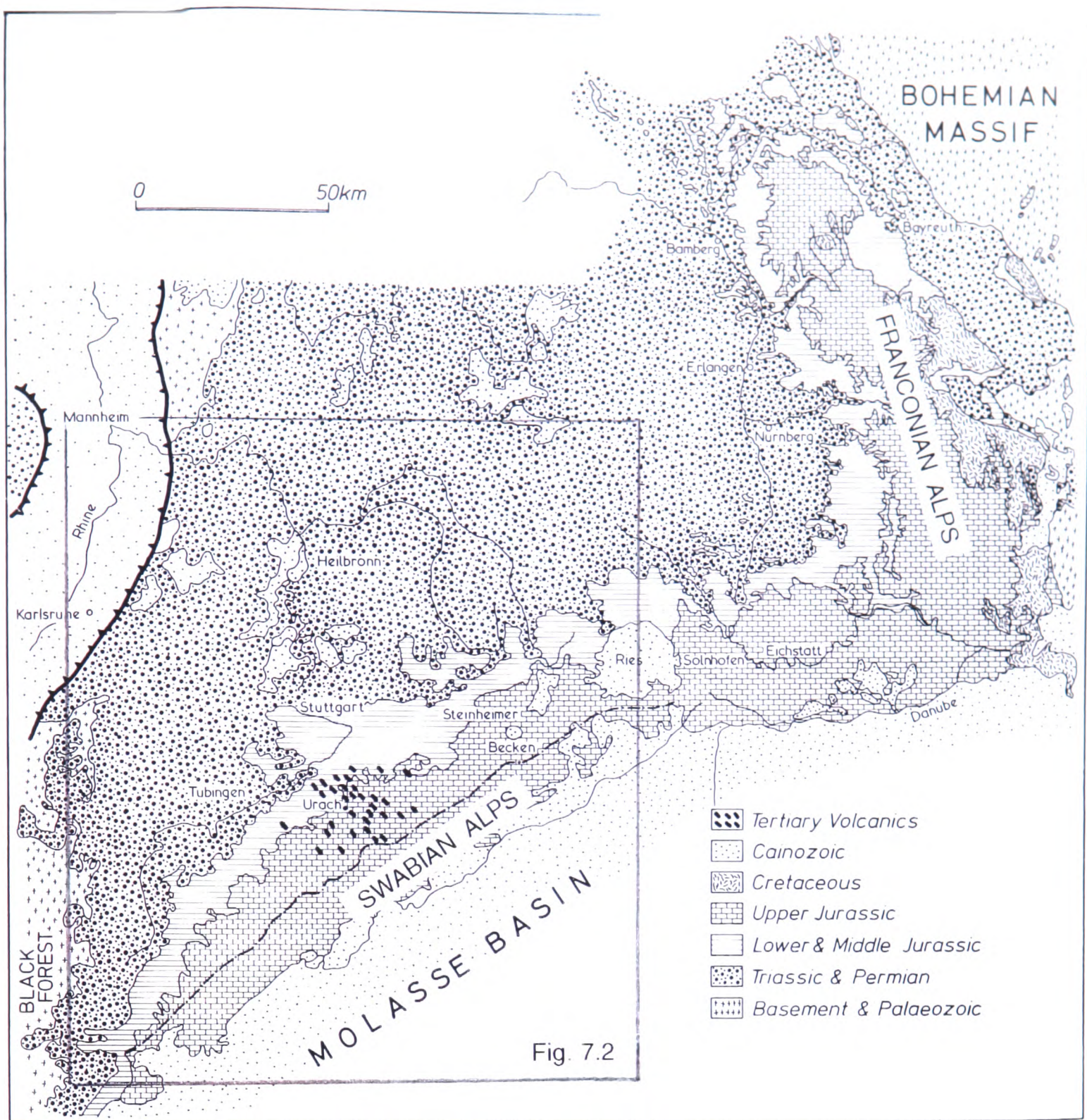


Figure 7.1a Geological sketch map of Southern Germany (modified from Ager, 1980)

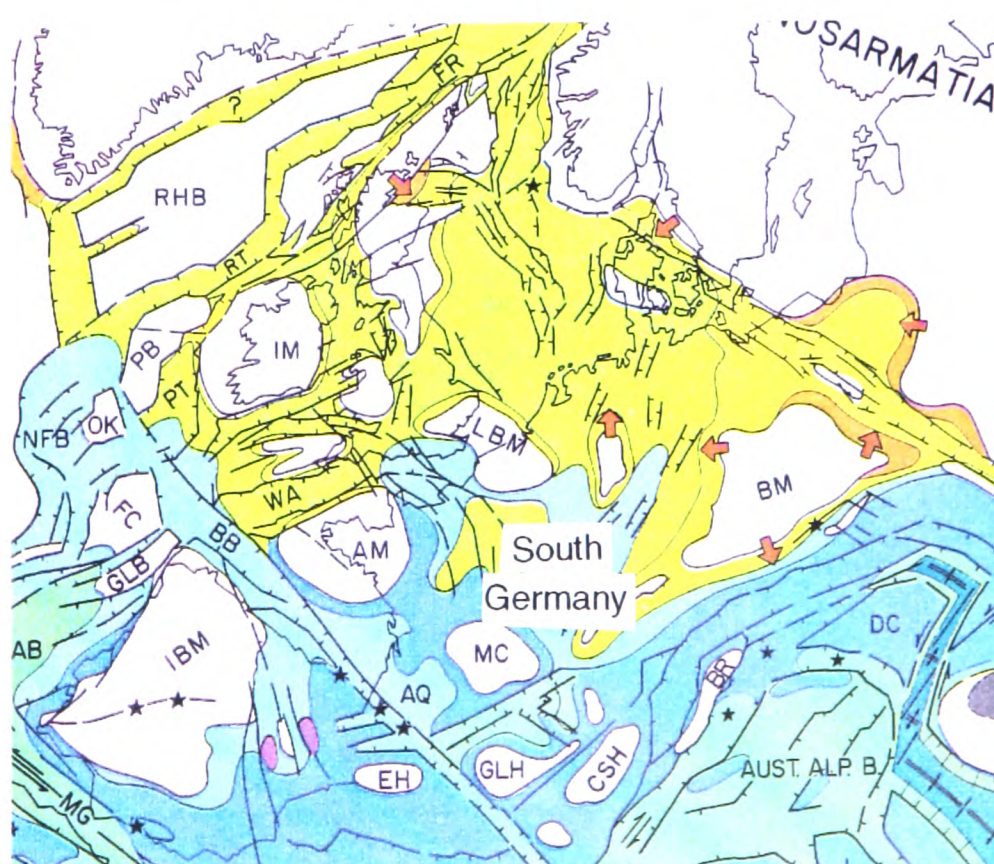


Figure 7.1b Paleogeographic setting of the South German Lower Jurassic (from Ziegler, 1988)

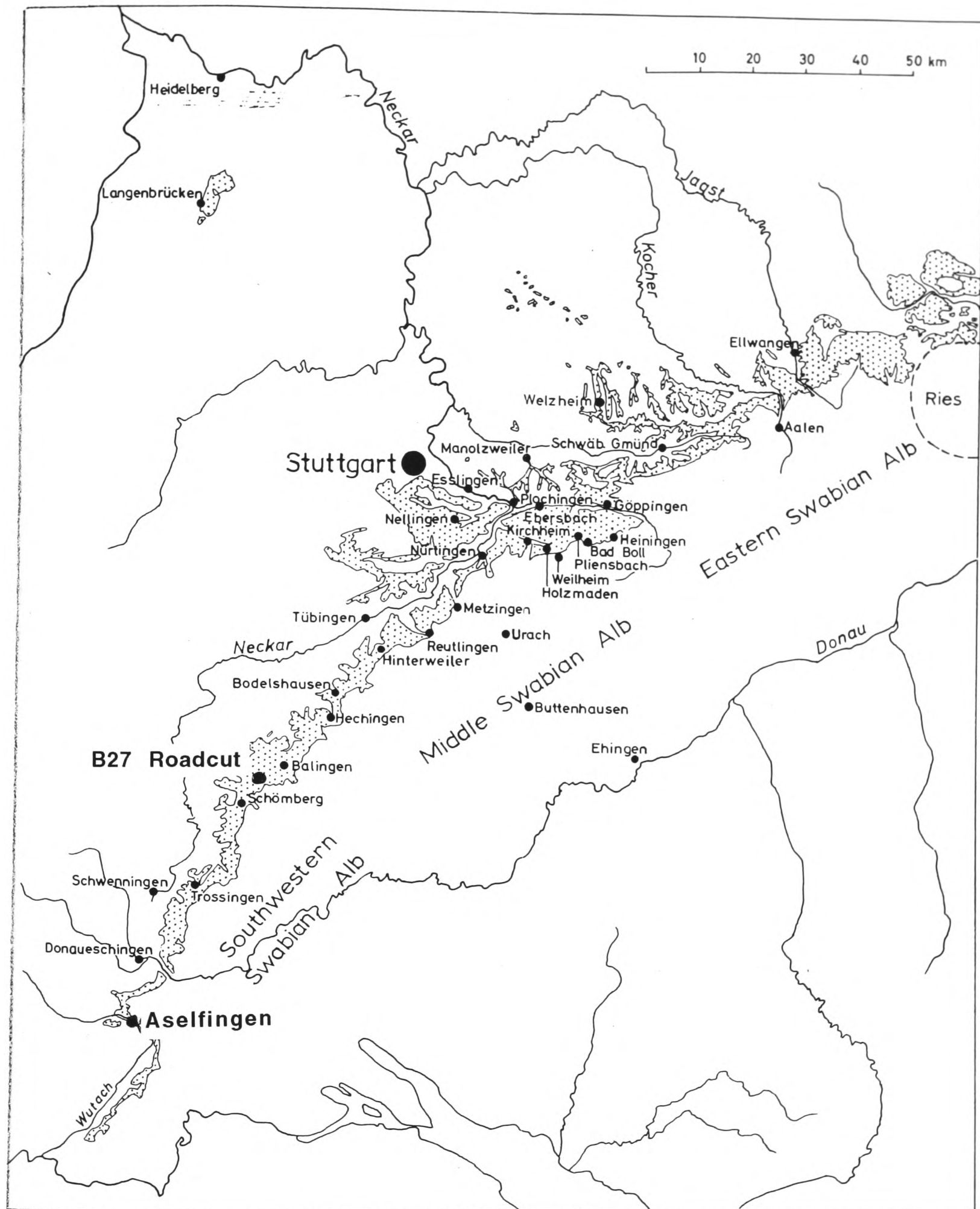


Figure 7.2 Outcrop of the Lower Jurassic in the Swabian Alps (from Urlich, 1977), showing study locations

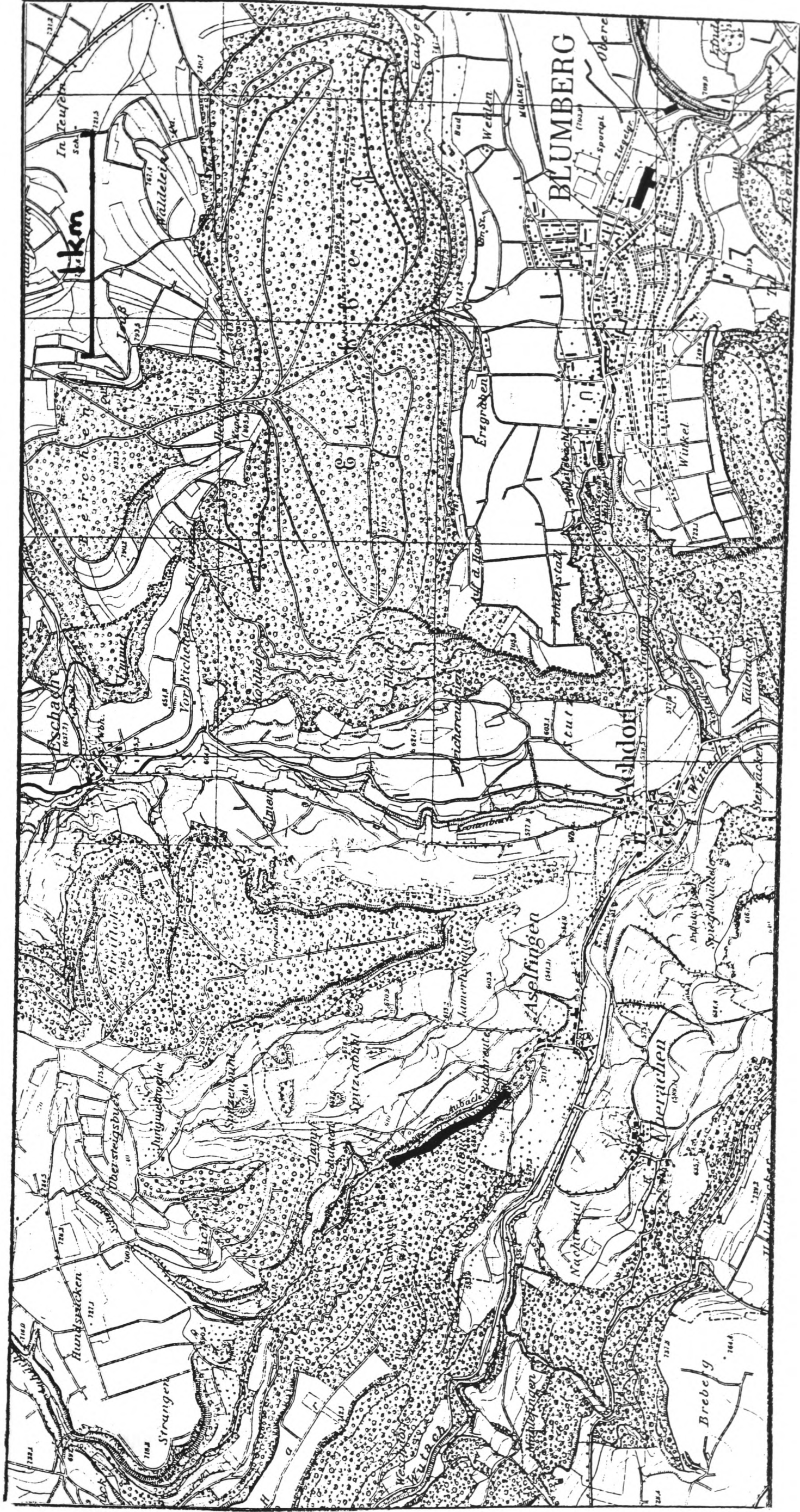


Figure 7.3 Locality map of the Aselfingen section (heavy line shows exposure)

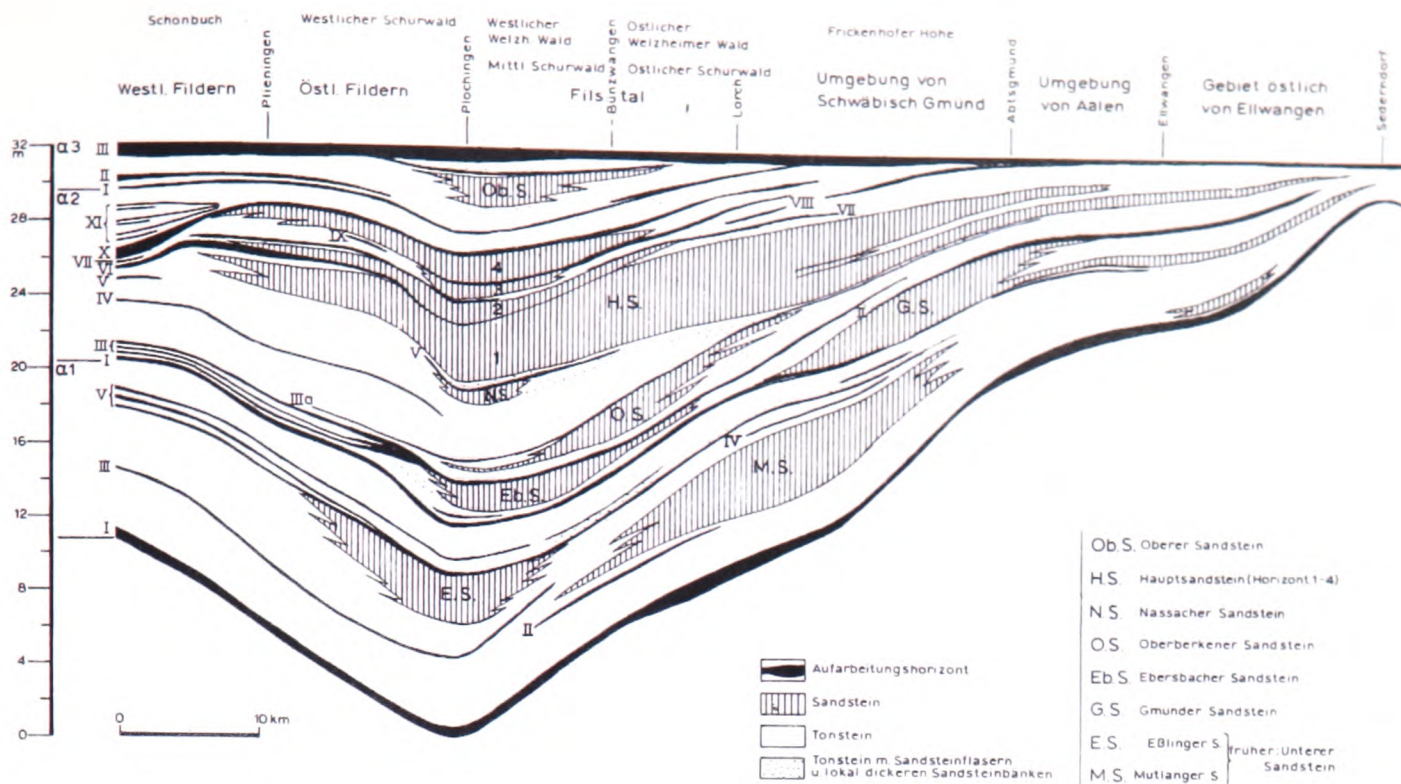


Figure 7.4a Lateral variations in the South German Hettangian (α_1 & α_2), from Bloos, 1976.



Figure 7.4b Typical facies of the Lower Jurassic at Aselfingen. Lias δ mudrocks, increasingly nodular towards the top, passing up into Lias ϵ limestones and bituminous shales.

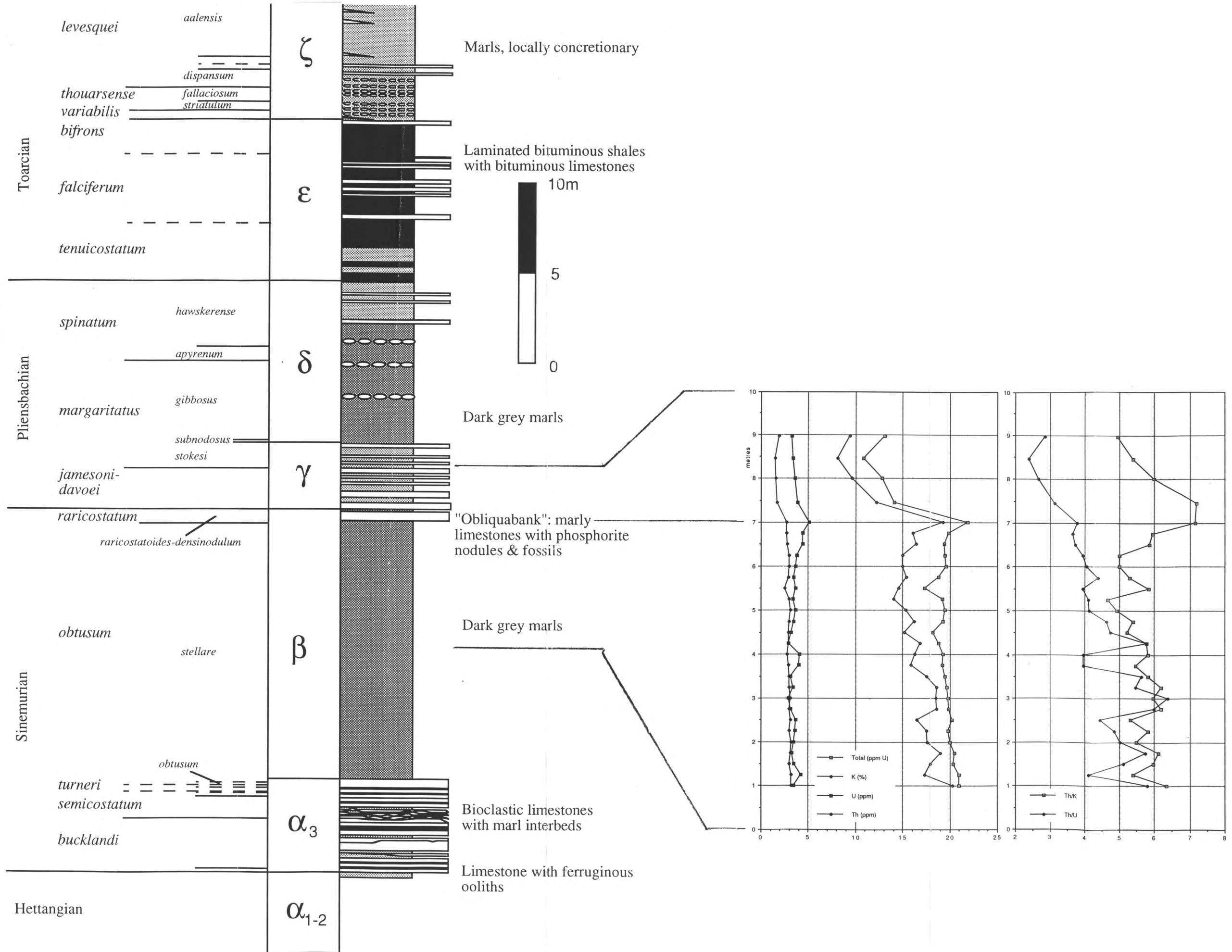


Figure 7.5 Log of the Lower Jurassic at Aselfingen compiled from data in Ulrichs (1977) supplemented by author's observations. Spectral gamma-ray data were recorded over the Late Sinemurian-Early Pliensbachian interval (see Appendix 1 for for tabulated data).

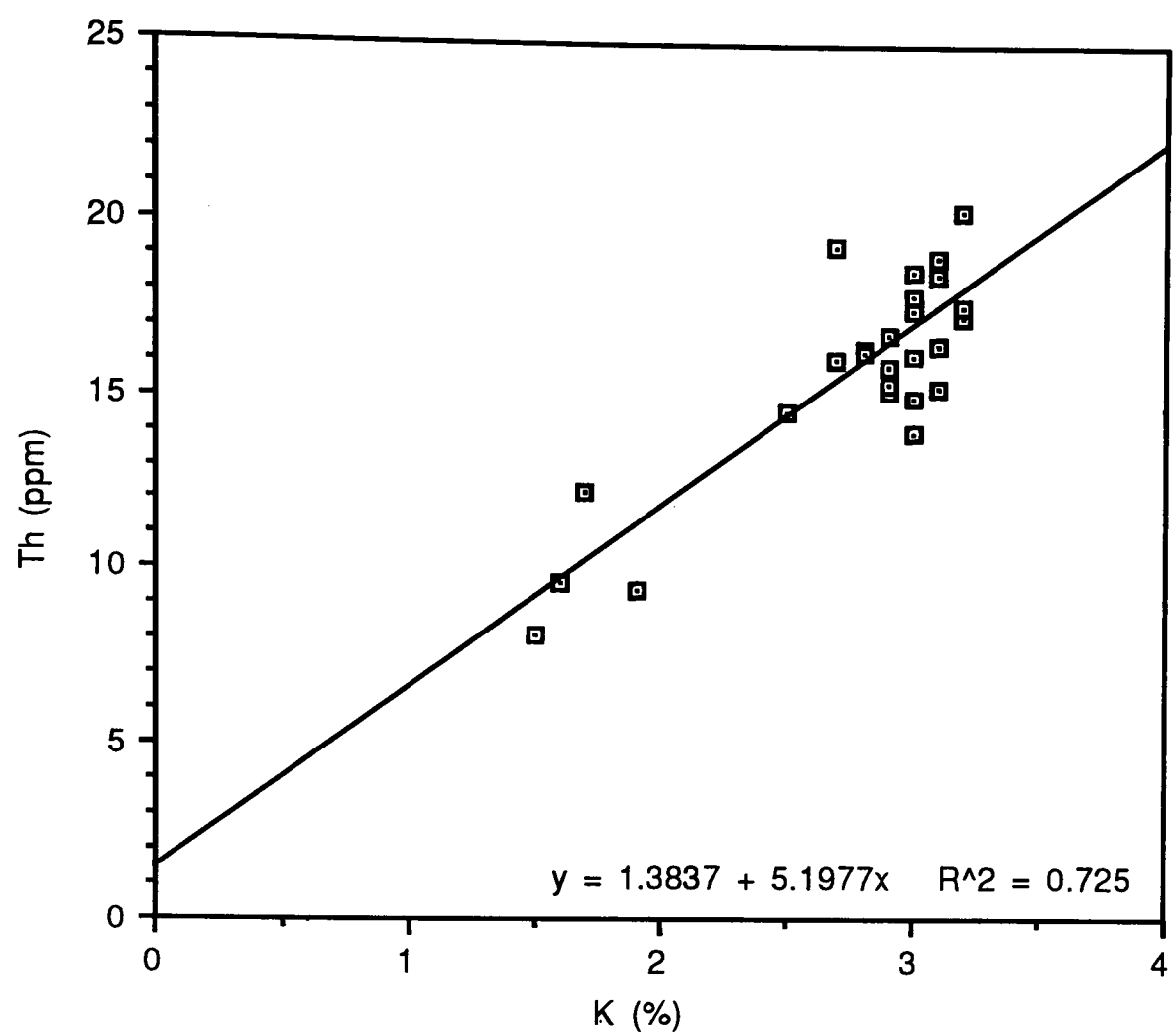


Figure 7.6a Thorium v. Potassium, Beta Shale, Aselfingen

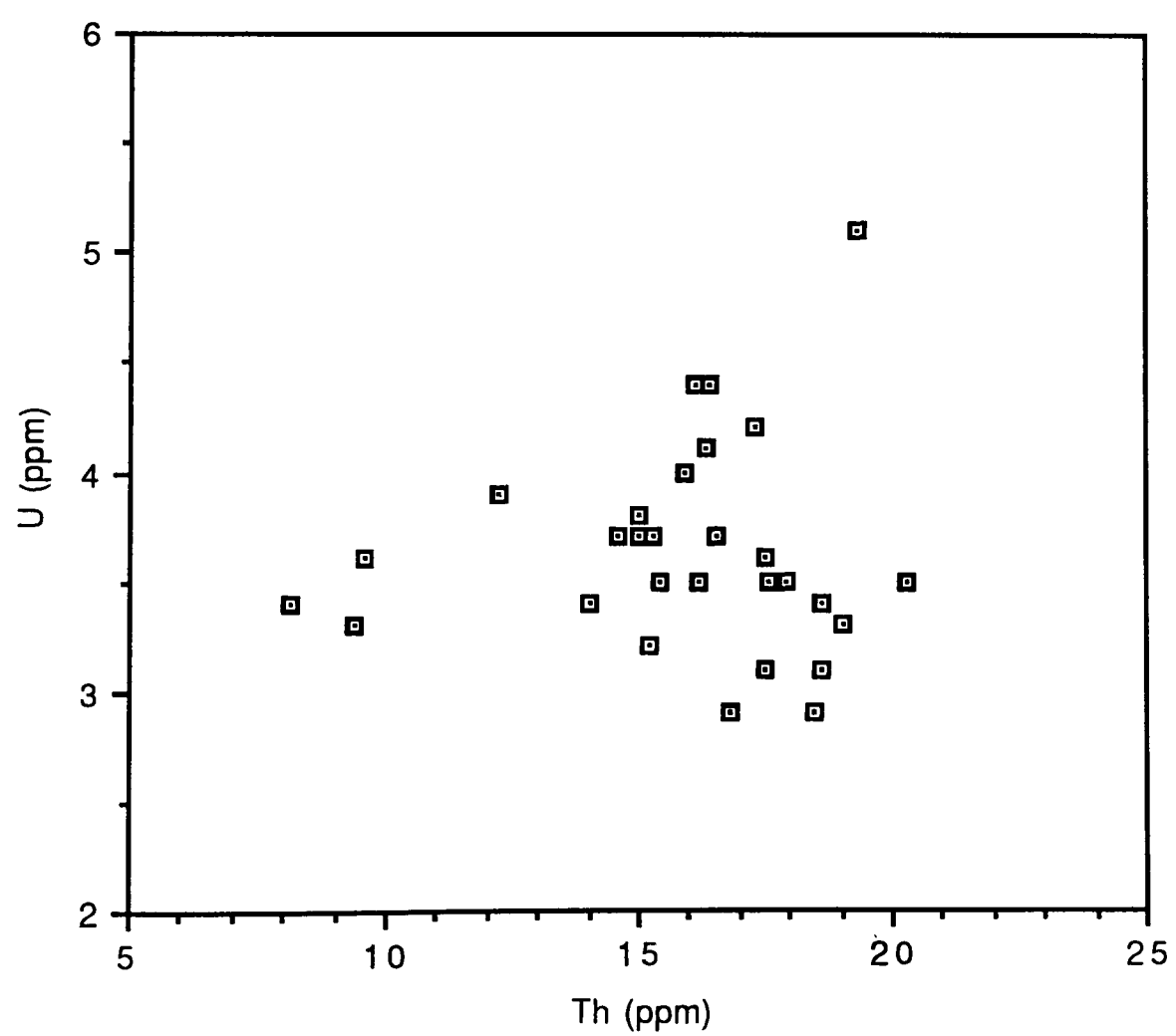


Figure 7.6b Thorium v. Uranium, Beta Shale, Aselfingen

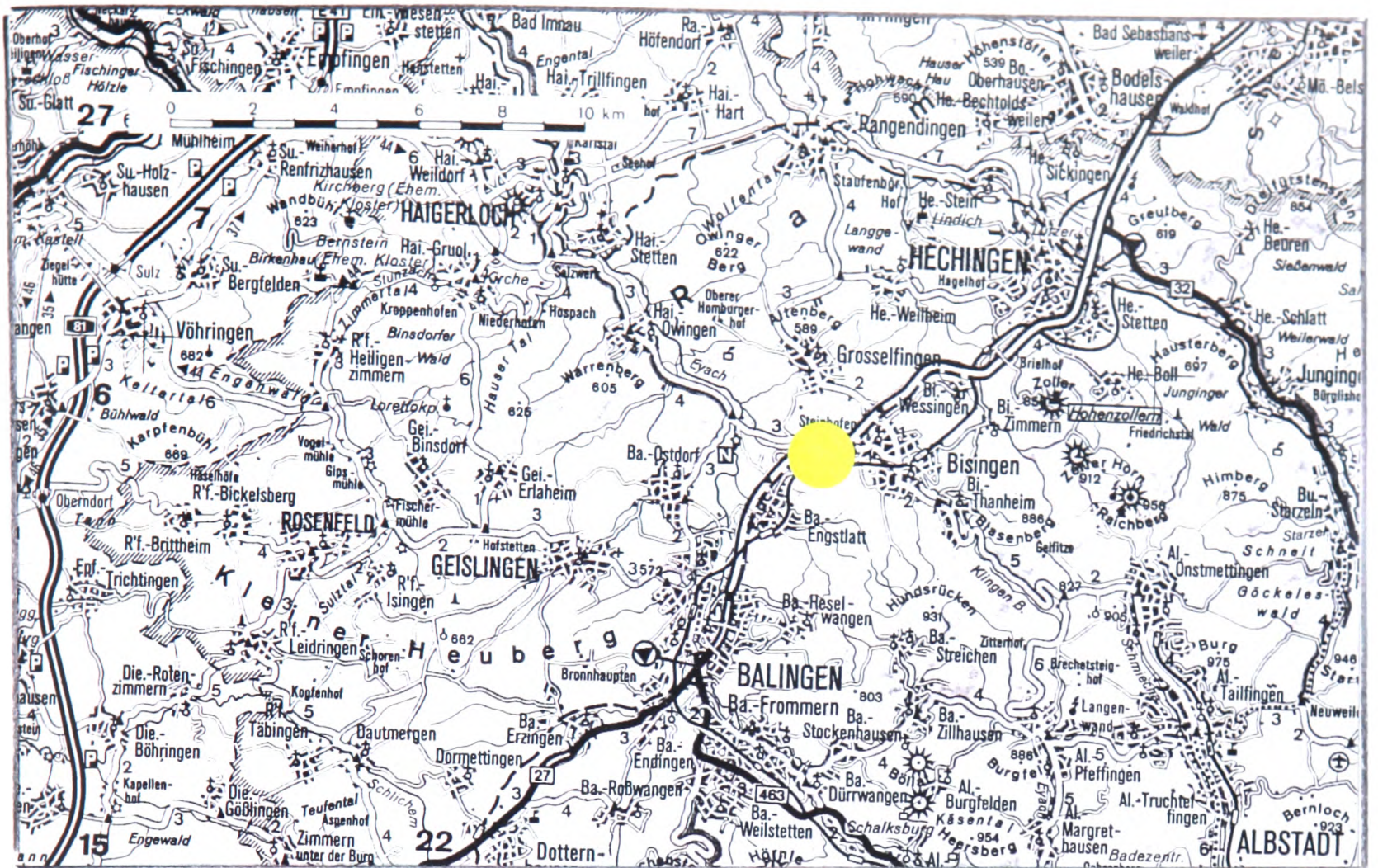


Figure 7.7a Location of new B27 roadcut shown by yellow spot (based on Reise- und Verkehrsverlag Große Straßenkarte Deutschland, Sheet 10)

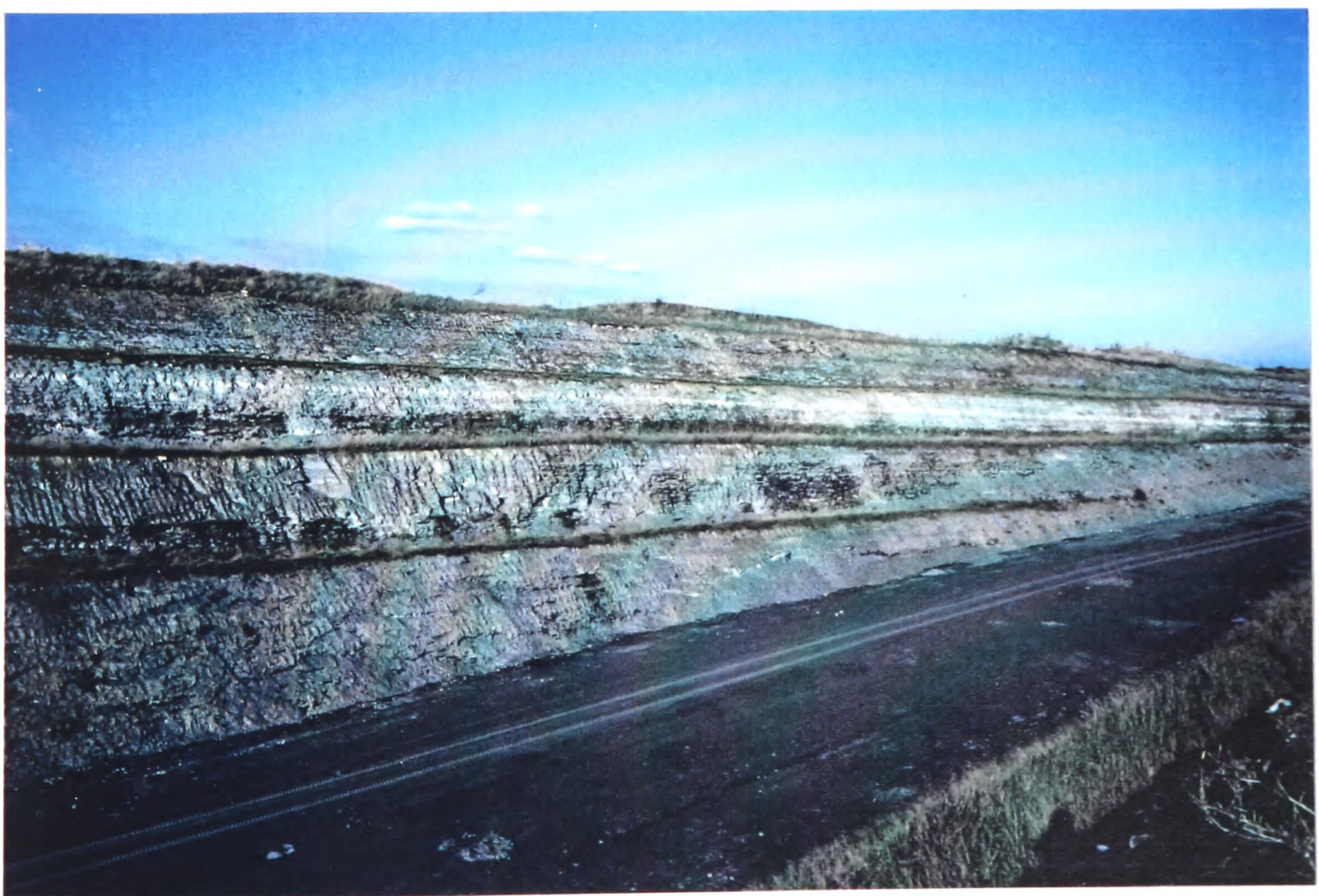


Figure 7.7b The logged face of the B27 roadcut showing benches 2-5 (see log, fig. 7.8)

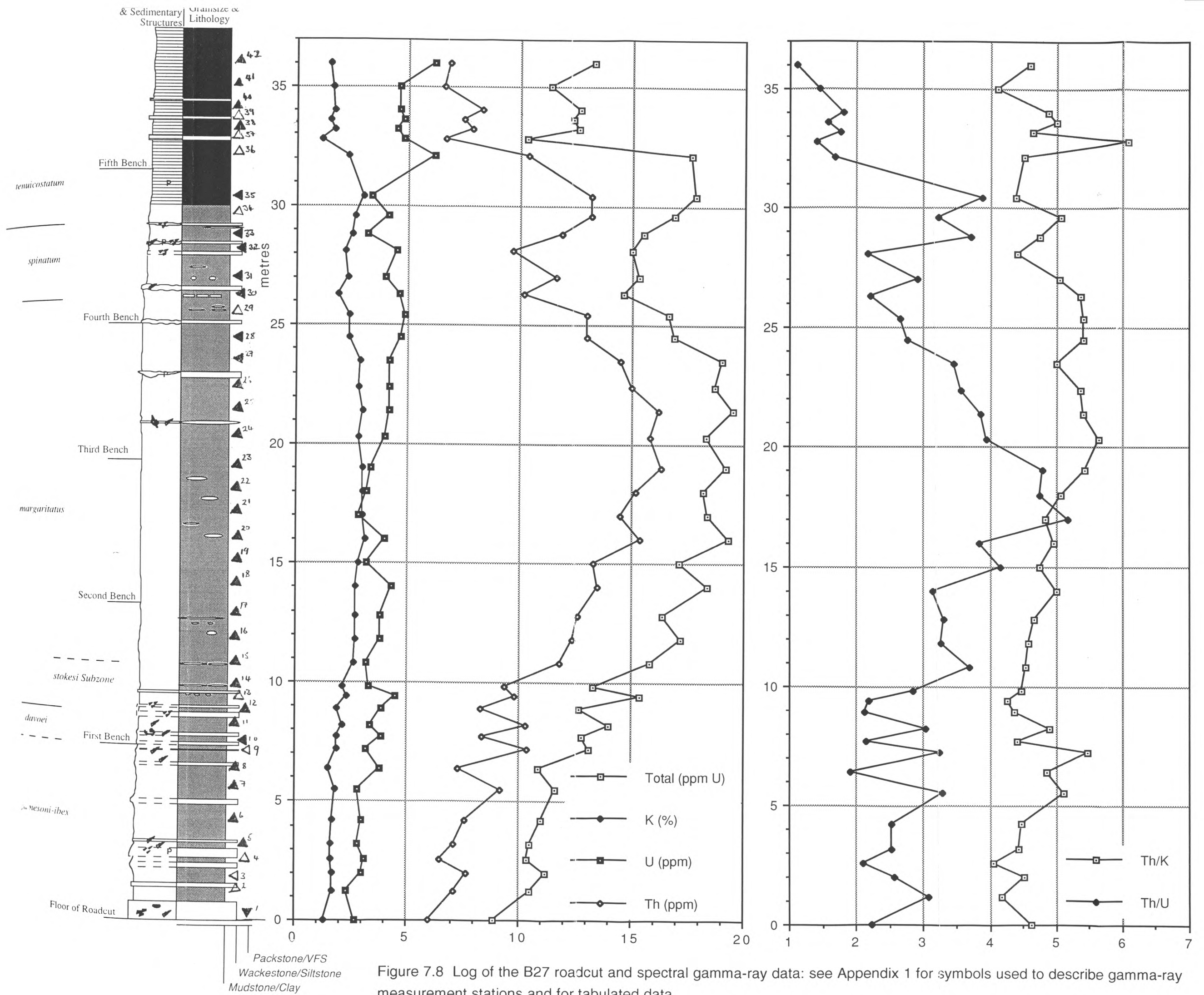


Figure 7.8 Log of the B27 roadcut and spectral gamma-ray data: see Appendix 1 for symbols used to describe gamma-ray measurement stations and for tabulated data

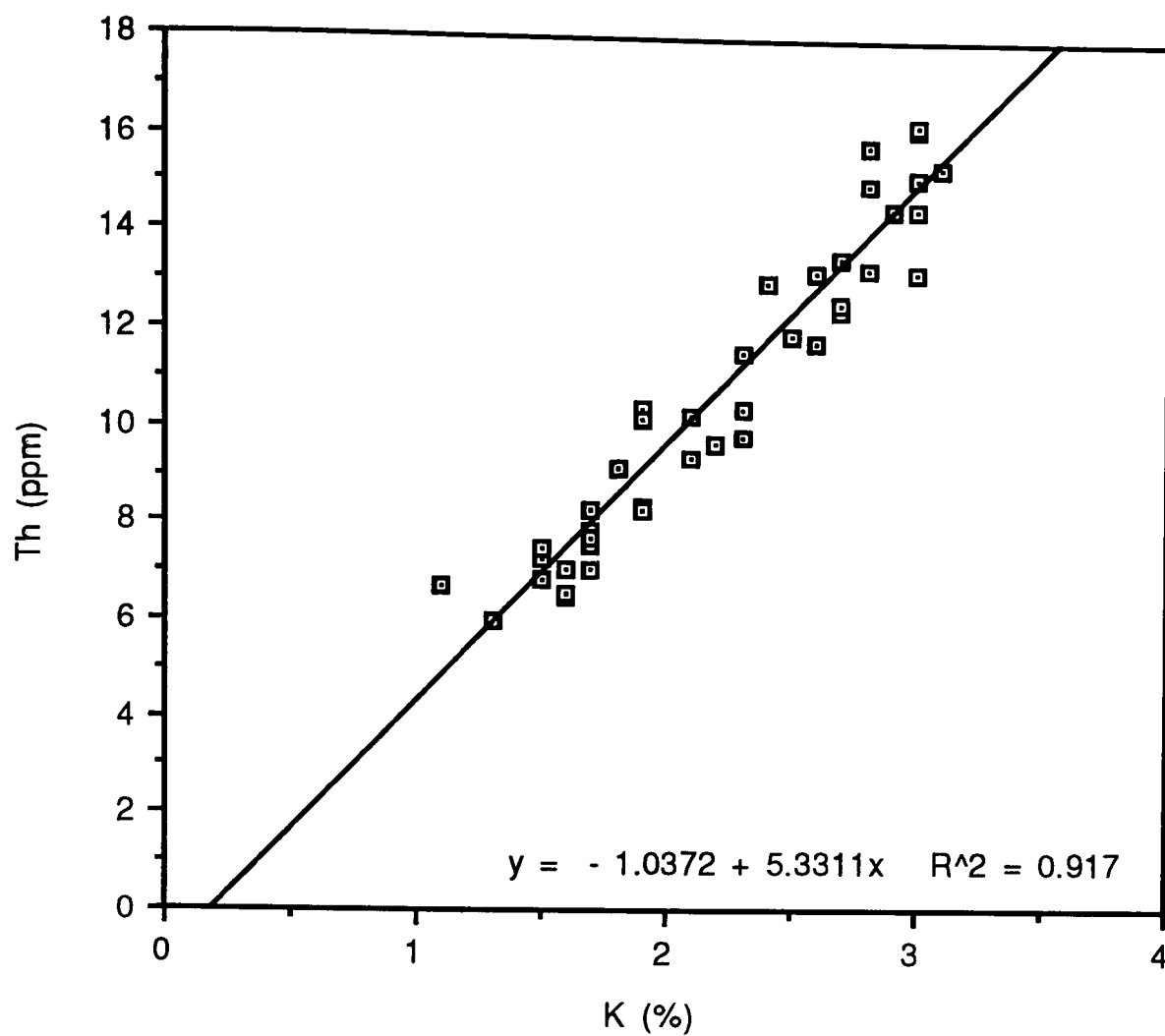


Figure 7.9a Thorium v. Potassium for the B27 roadcut, S. Germany

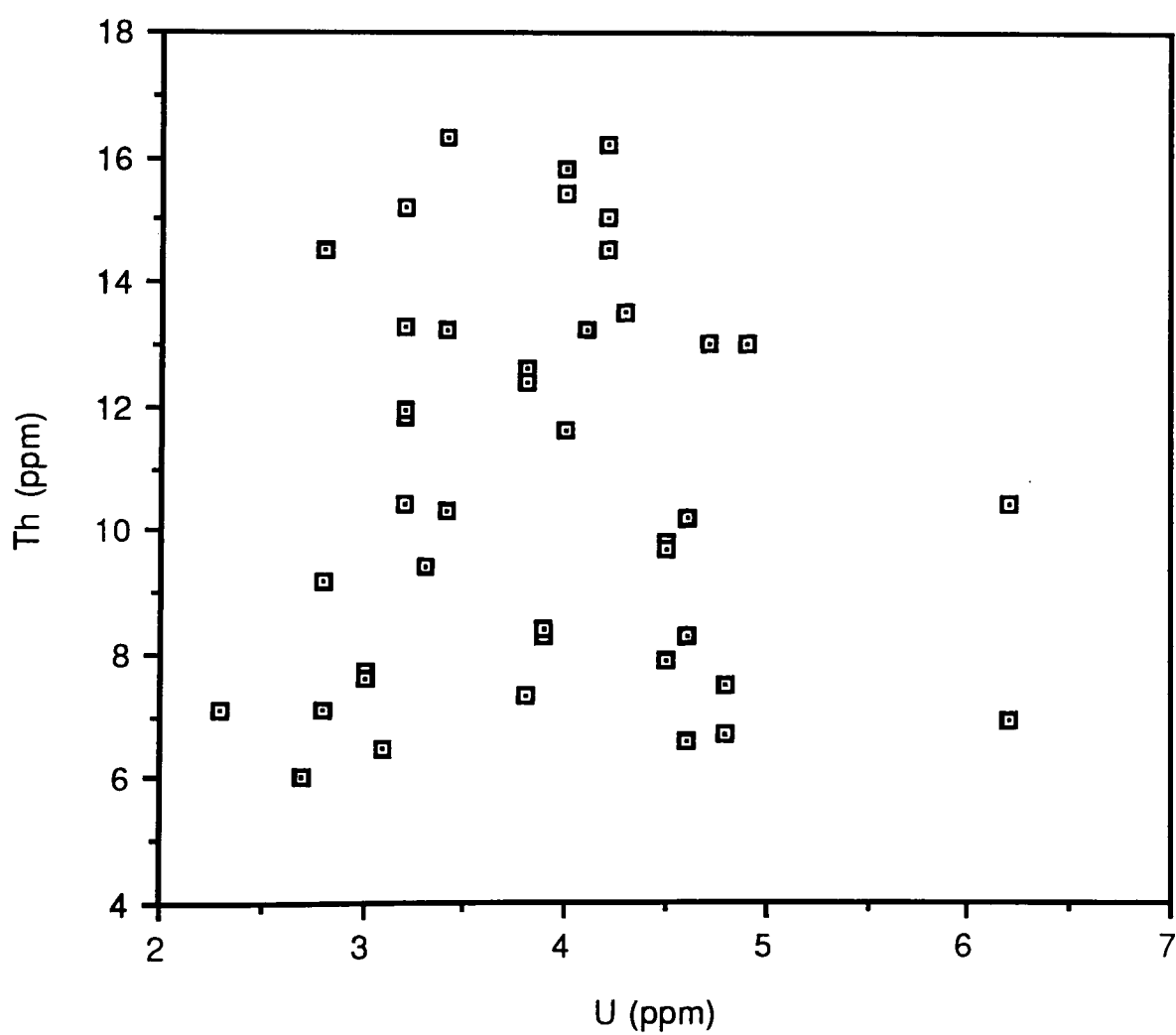


Figure 7.9b Thorium v. Uranium for the B27 roadcut, S. Germany

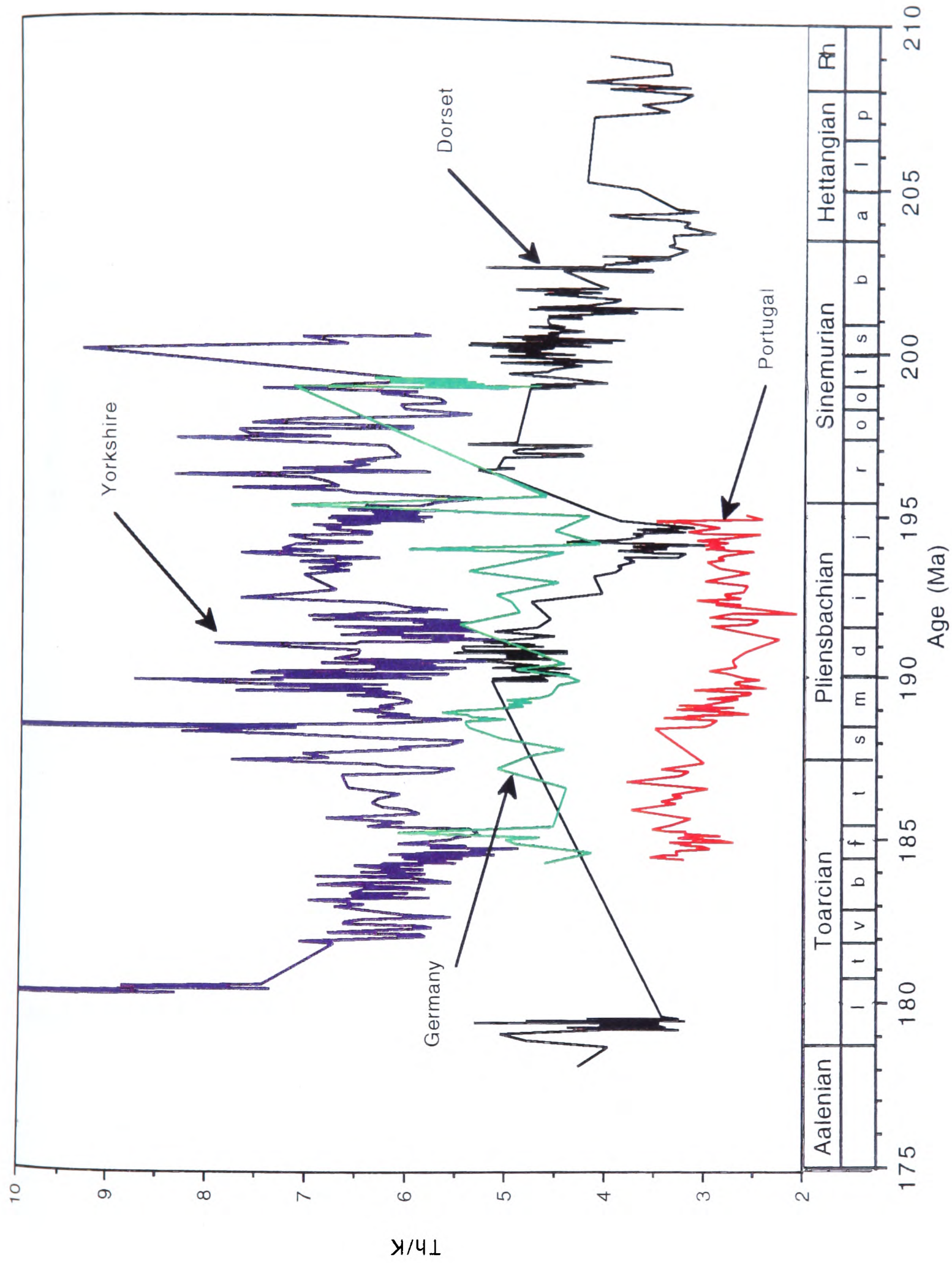


Figure 7.10 Th/K Ratios in the Lower Jurassic of Western Europe

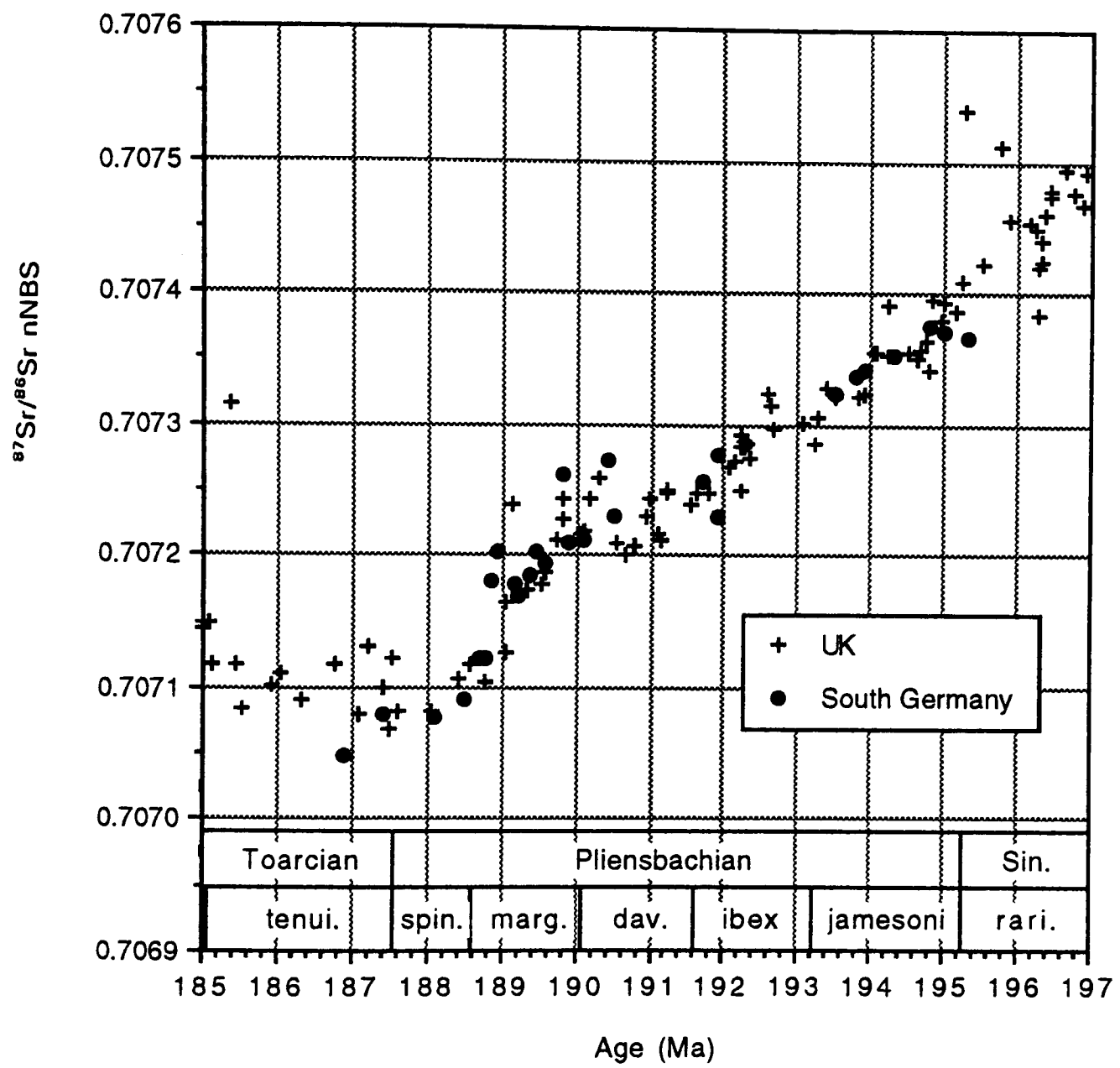


Figure 7.11 $^{87}\text{Sr}/^{86}\text{Sr}$: comparison of UK data (Jones, 1992) and German data (this Thesis)

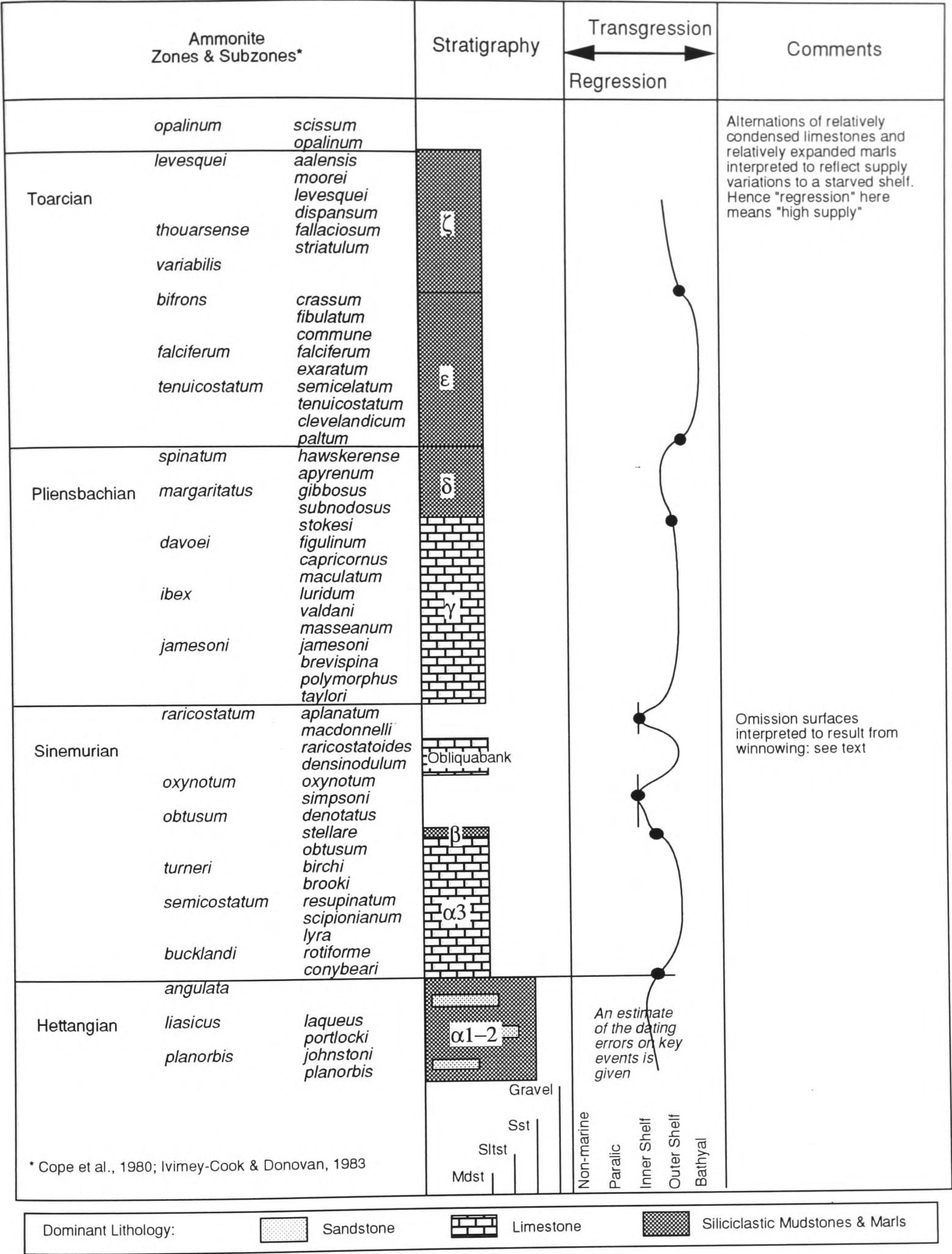


Figure 7.12 Summary of stratigraphic events in the Lower Jurassic of Southern Germany

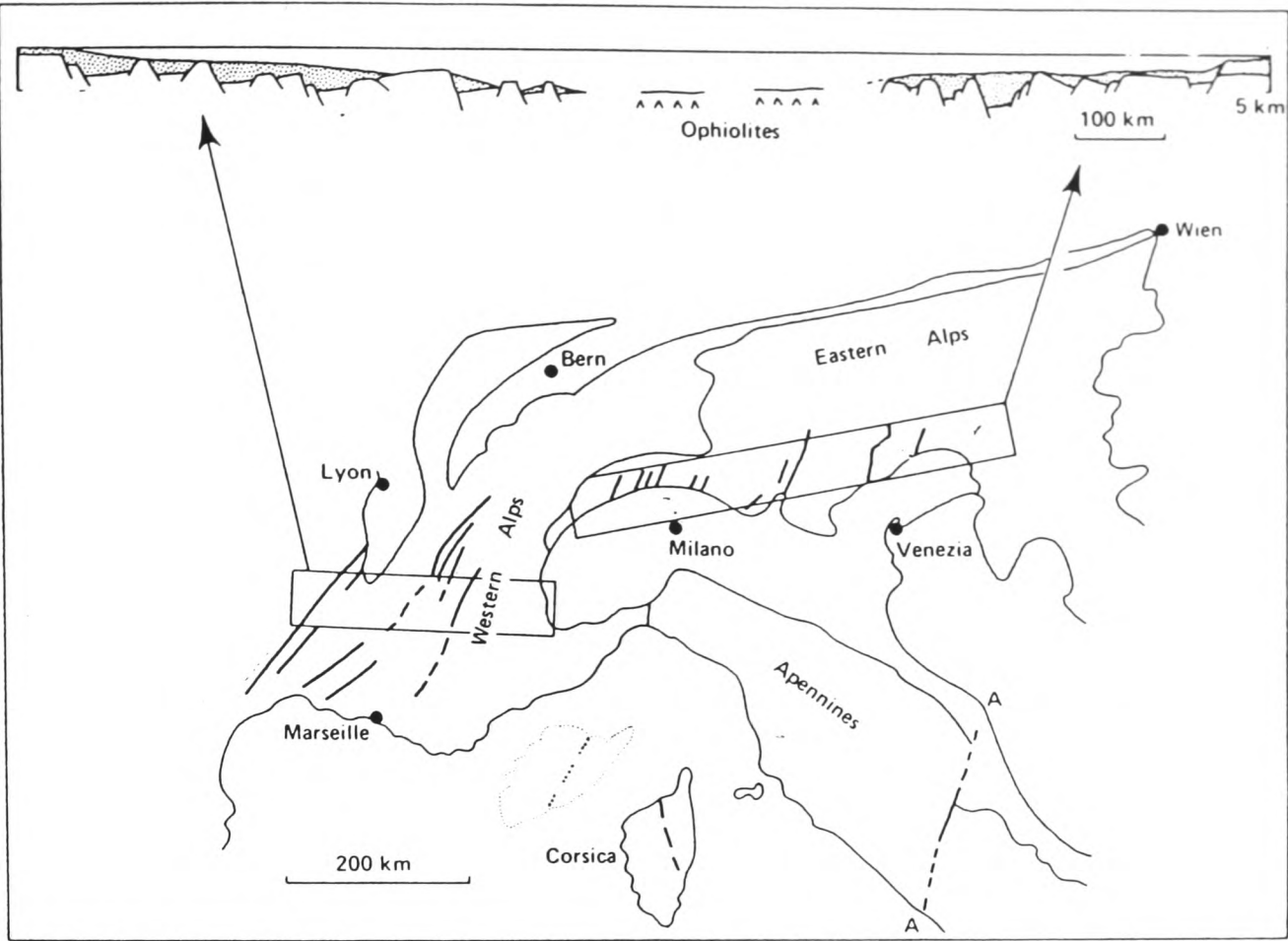


Figure 8.1a The Western Alps in their plate-tectonic context (from Lemoine, 1983). Heavy lines indicate faults known to be active in the Lower Jurassic. The upper section shows a reconstruction of Late Jurassic margins: dotted areas are Jurassic sediments.

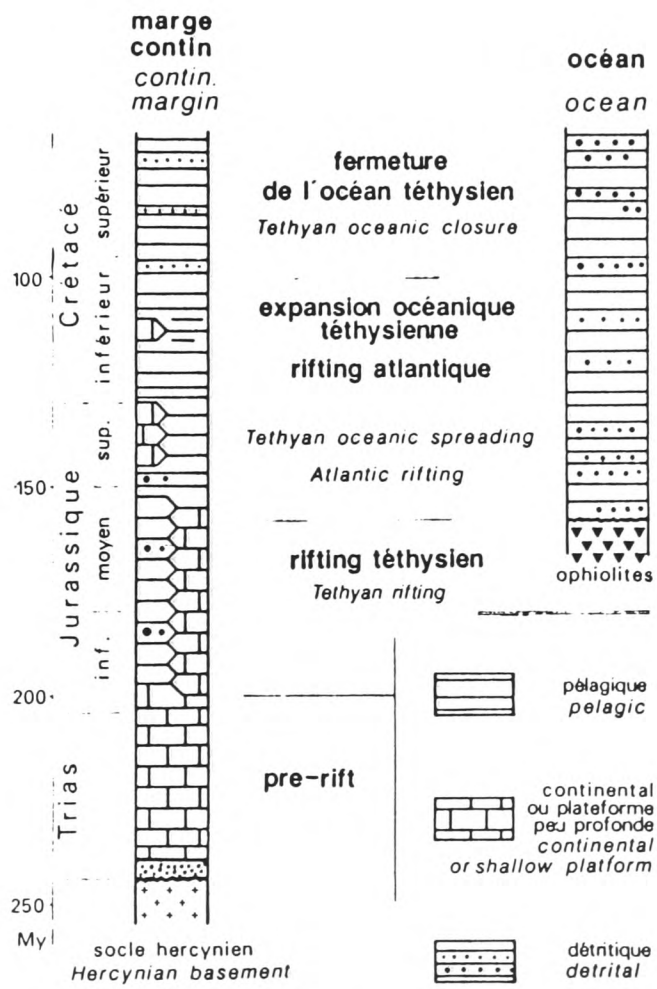


Figure 8.1b Summary stratigraphy of the Western Alps (from Lemoine & de Graciansky, 1988)

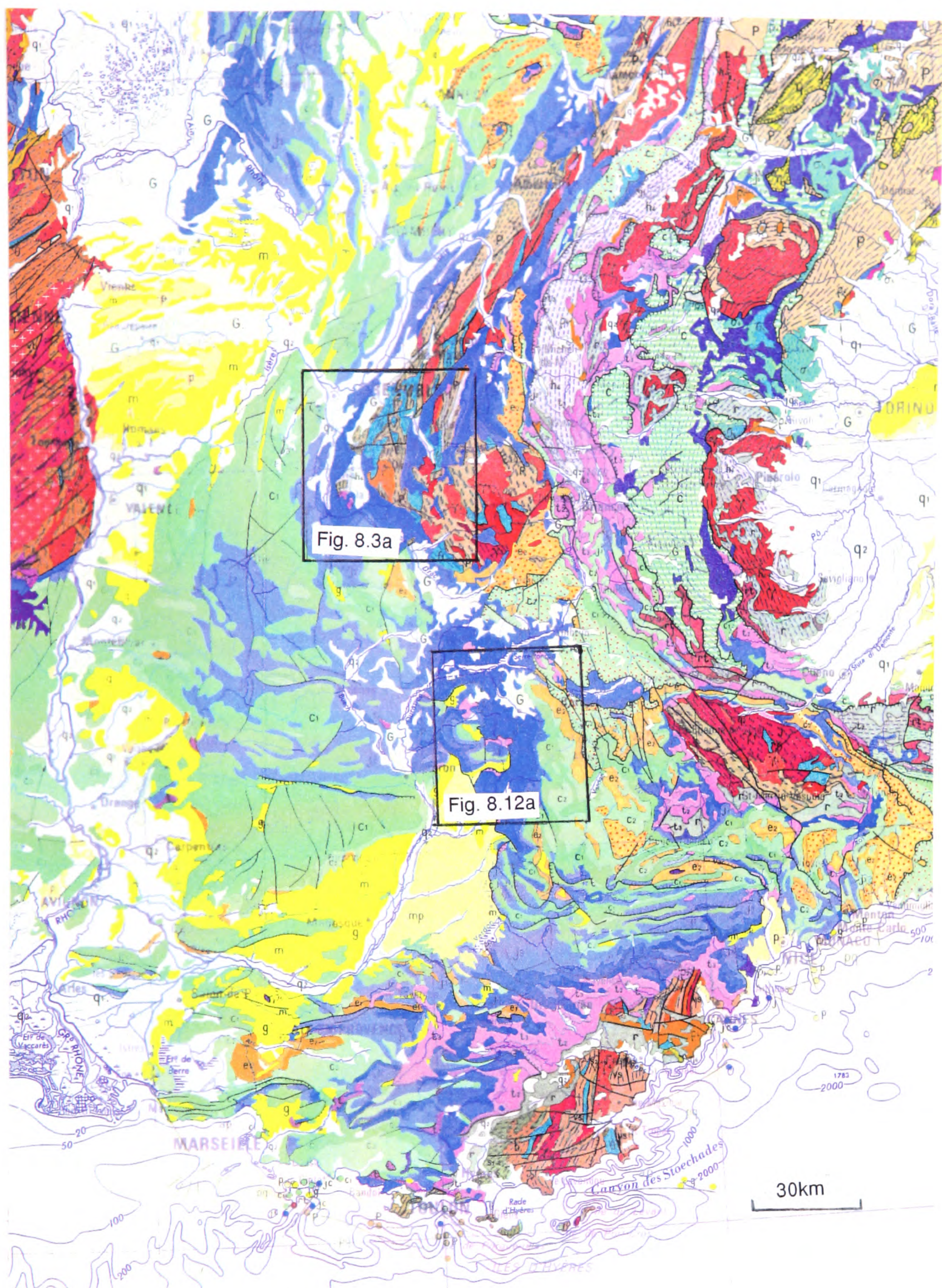


Figure 8.2 Geological map of the external Alps in S.E France: Lower Jurassic outcrop shown in dark blue and location of study areas highlighted (from Carte géologique de la France, 1:1 500 000, BRGM, 1980)

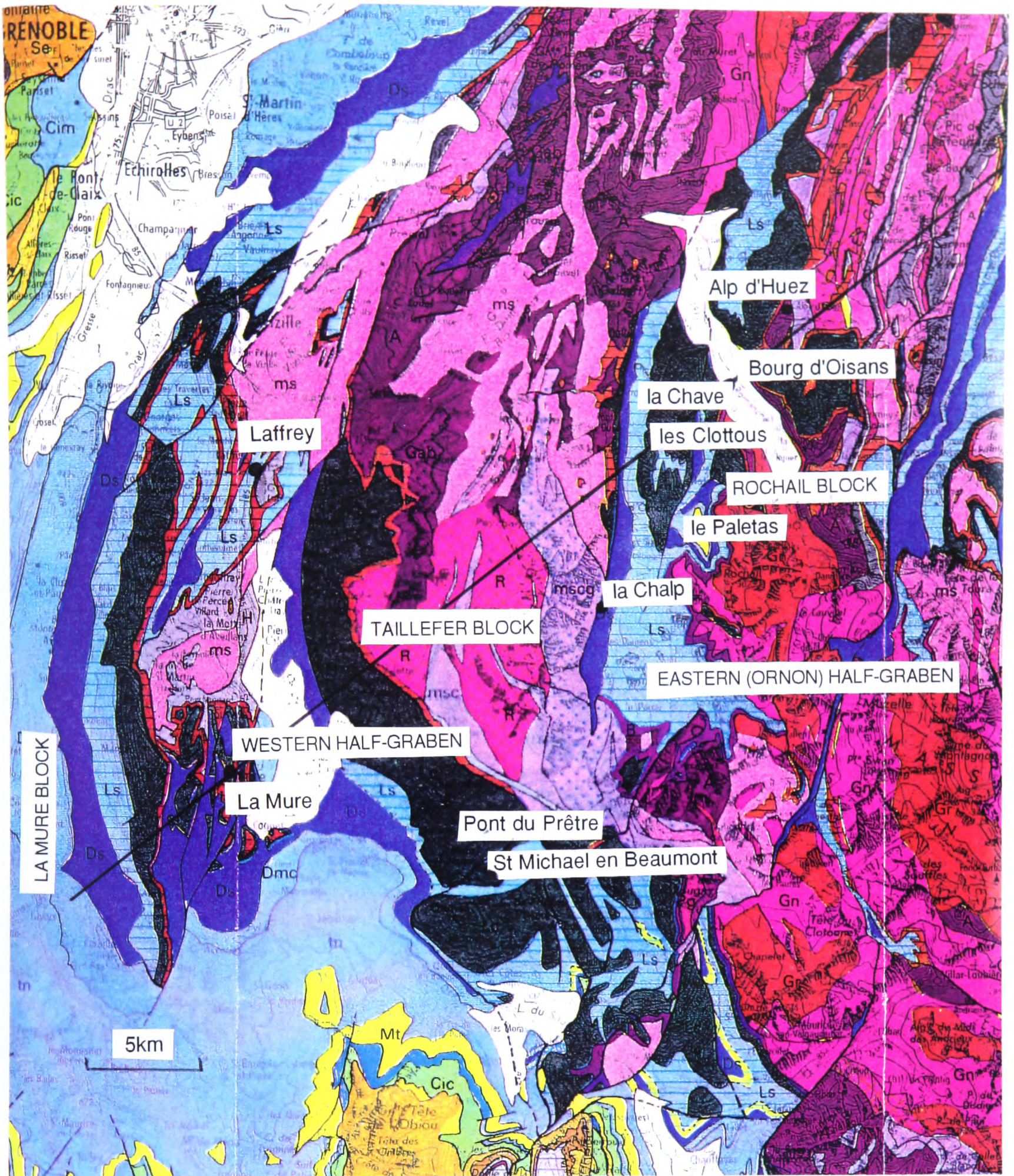
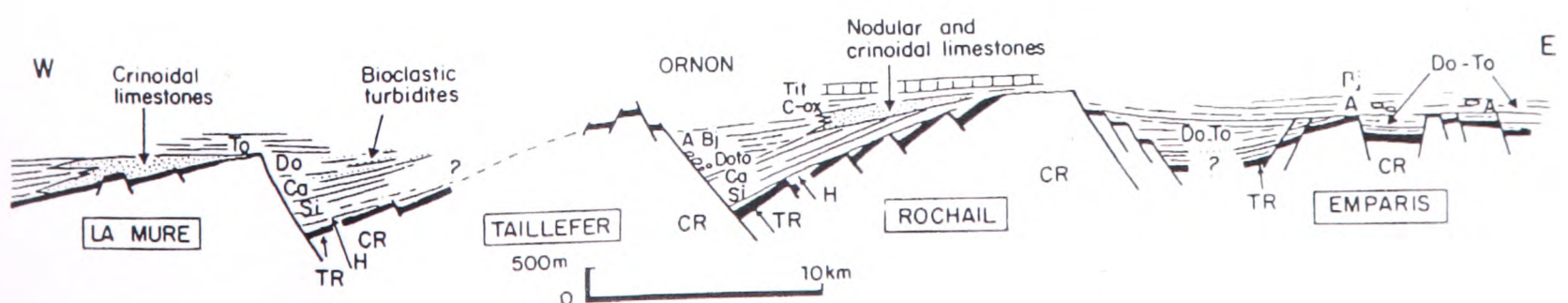


Figure 8.3a Locality map for the Bourg d'Oisans-La Mure area (from Gidon, undated). Ls = Schistose Lias (pale blue), Lc = Calcareous Lias (dark green). Basement rocks in pinks and reds. Approximate line of figure 8.3b indicated



Palinspastic reconstruction (Late Jurassic) of four tilted blocks and associated half-grabens: the basement crystalline mass to the East of the City of Grenoble. Cr, Crystalline basement (including the Permo-Carboniferous continental deposits, e.g. in La Mure block). TR, Triassic. H, Hettangian. Si, Sinemurian. Ca, Carixian. Do, Domerian. To, Toarcian. A, Aalenian. Bj, Bajocian. C-C, Callovian-Oxfordian. Tit, Tithonian.

Figure 8.3b Restored cross-section (from Lemoine et al 1986): approximate line shown in figure 8.3a.



Figure 8.4a The Bourg d'Oisans half-graben. Dashed line marks the top of the basement, deformed rift-fill arrowed. Note that the photograph has been printed in reverse to conform with the interpretation below.

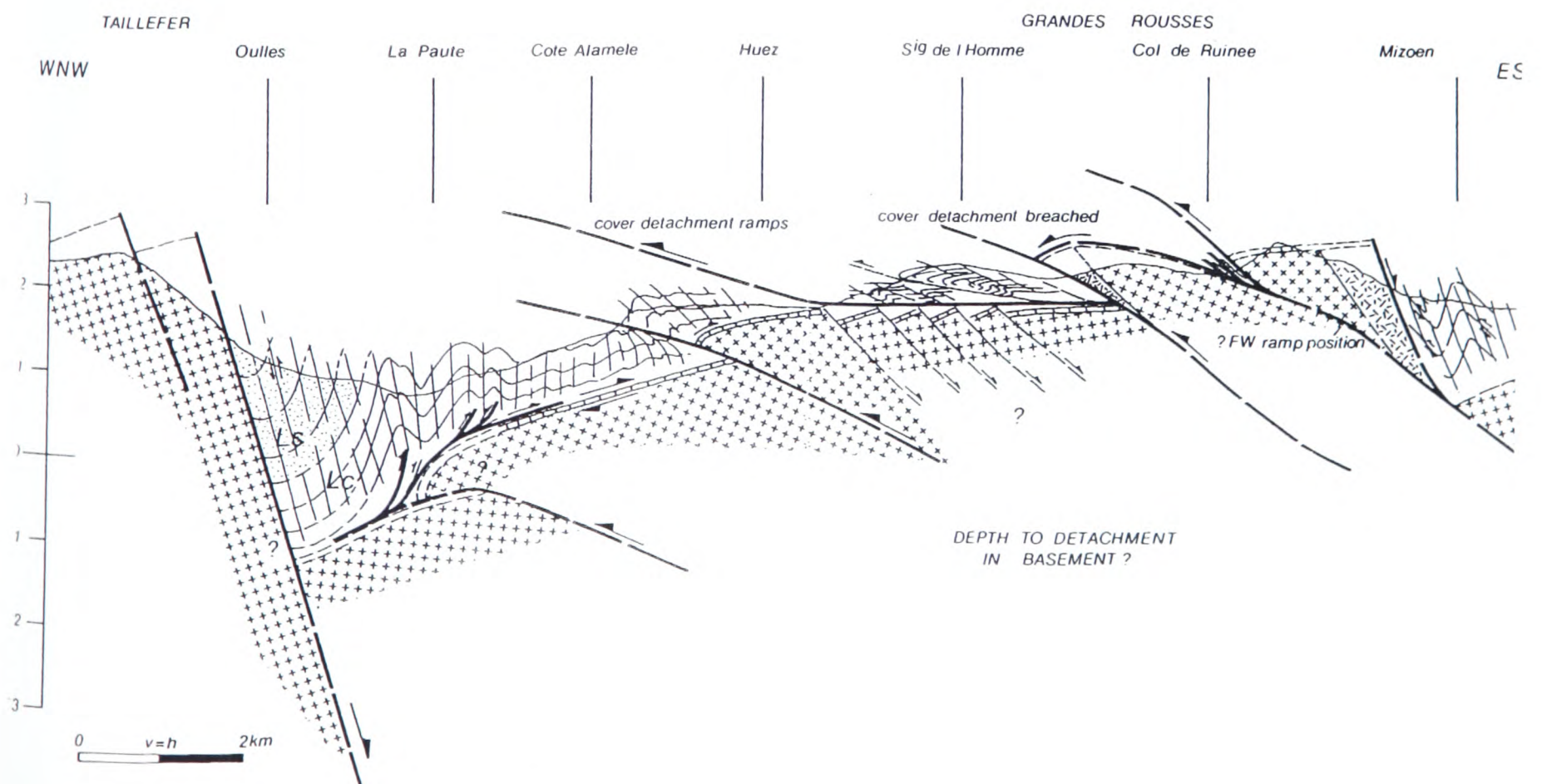


Figure 8.4b Interpretation of the Bourg d'Oisans area in terms of Alpine shortening of a Lower Jurassic half-graben (from Gillcrist, 1988)

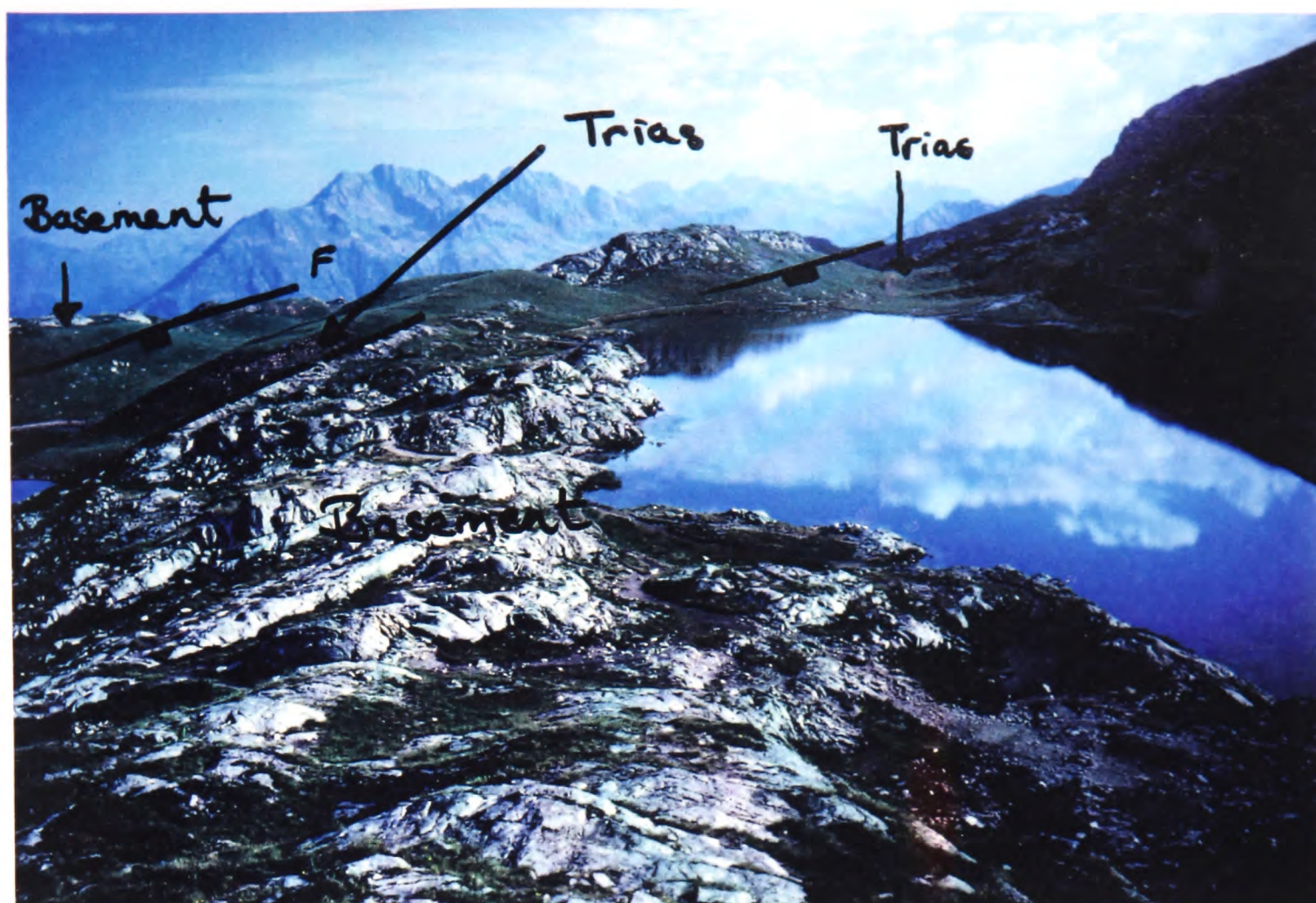


Figure 8.5a Early rifting: faults with a spacing of 10's m and metre-scale displacement, displacing Triassic and earliest Jurassic rocks. Plateau above Alp d'Huez

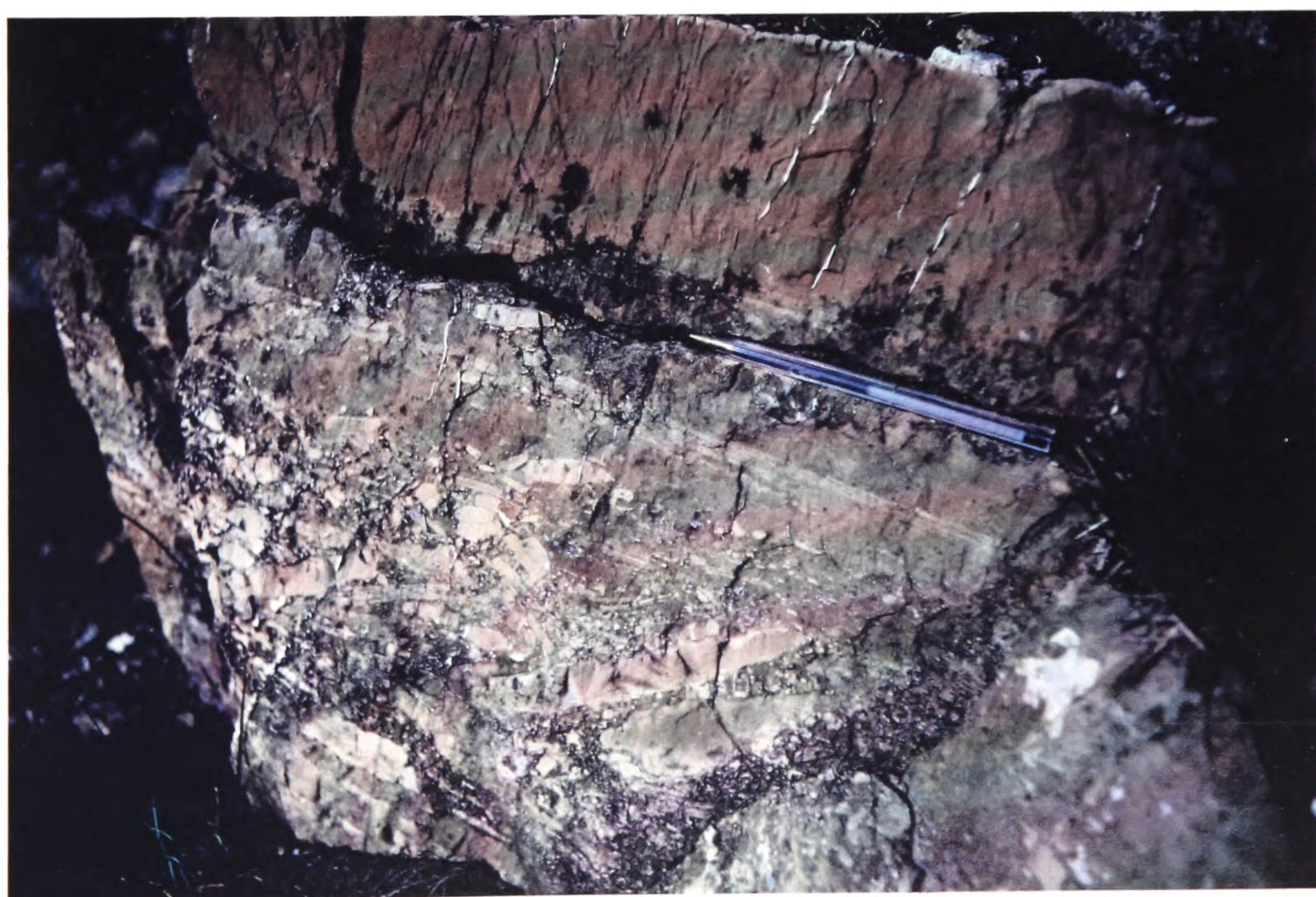


Figure 8.5b Triassic pre-rift facies: "flat pebble" breccia and algal lamination

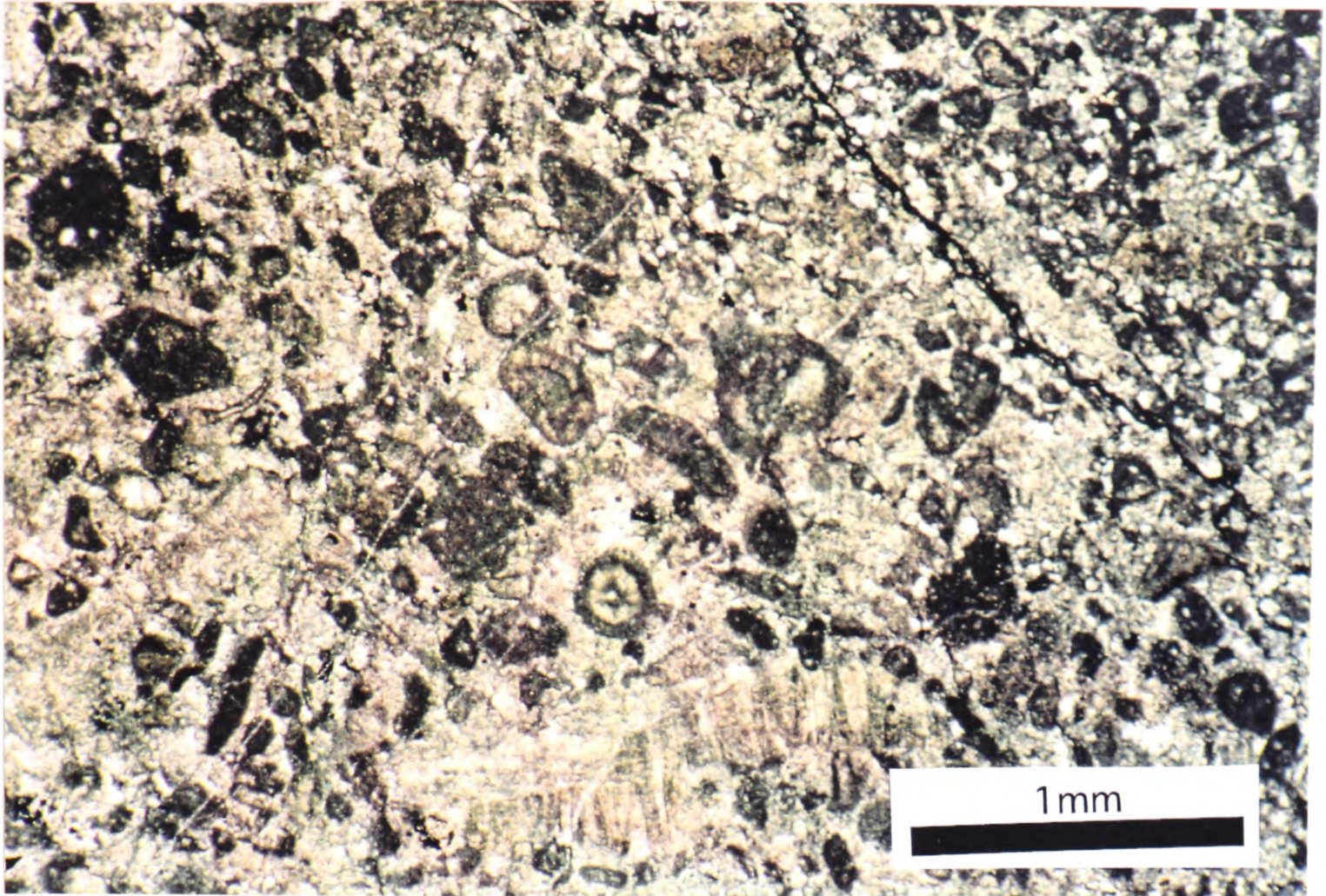


Figure 8.6a Peletal and oolitic grainstone from the Hettangian at la Paletas (sample FW39, ppl)

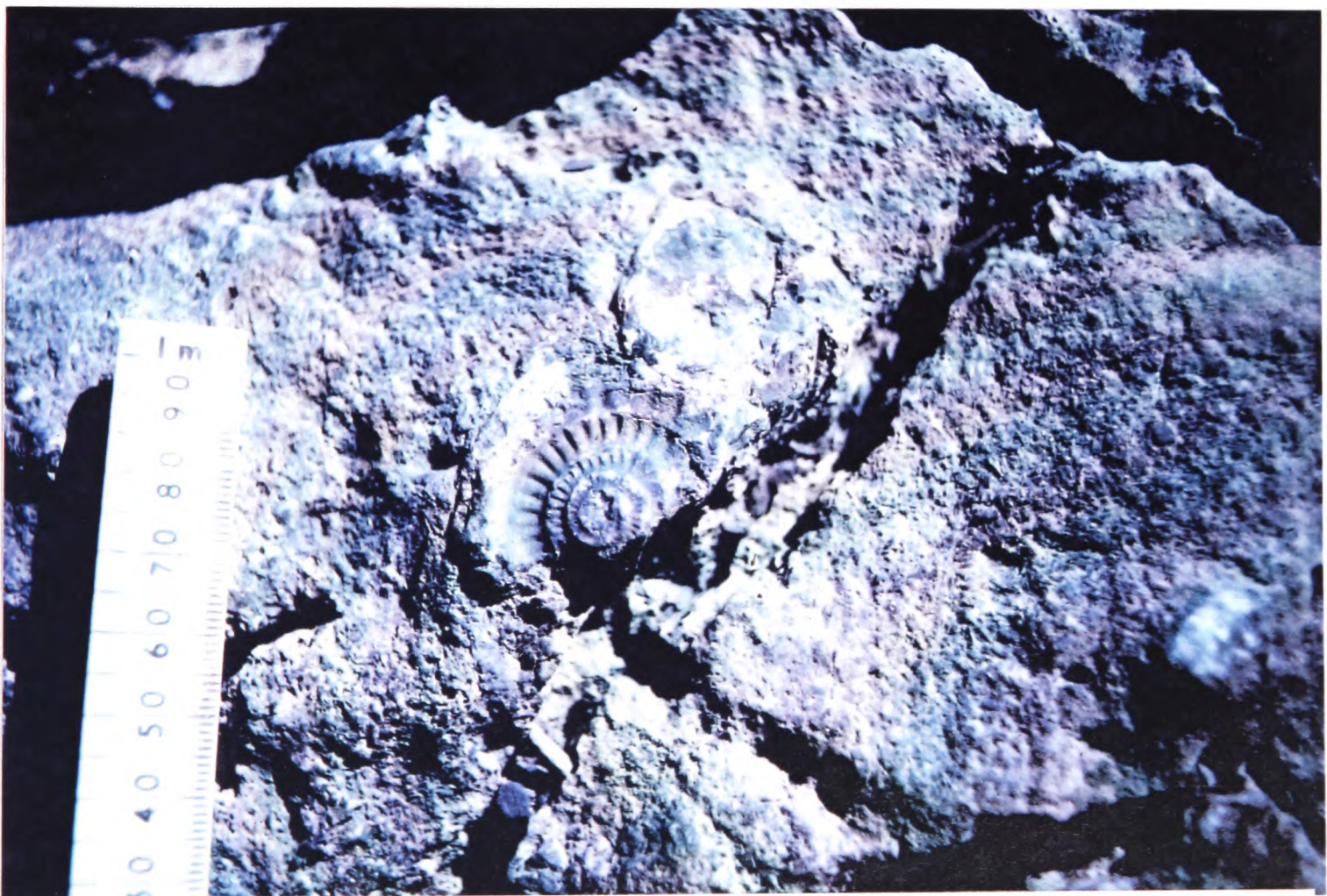


Figure 8.6b Top bed of carbonate section, la Chave. Probably an *Arnioceras* suggesting *semicostatum* to early *obtusum* Zones. Possibly *Caloceras* (mid-Hettangian). Identification courtesy of Prof. D. T. Donovan.



Figure 8.7a Olistolith of Triassic volcanic rock in Liassic matrix : la Chalp. See interpretation below.

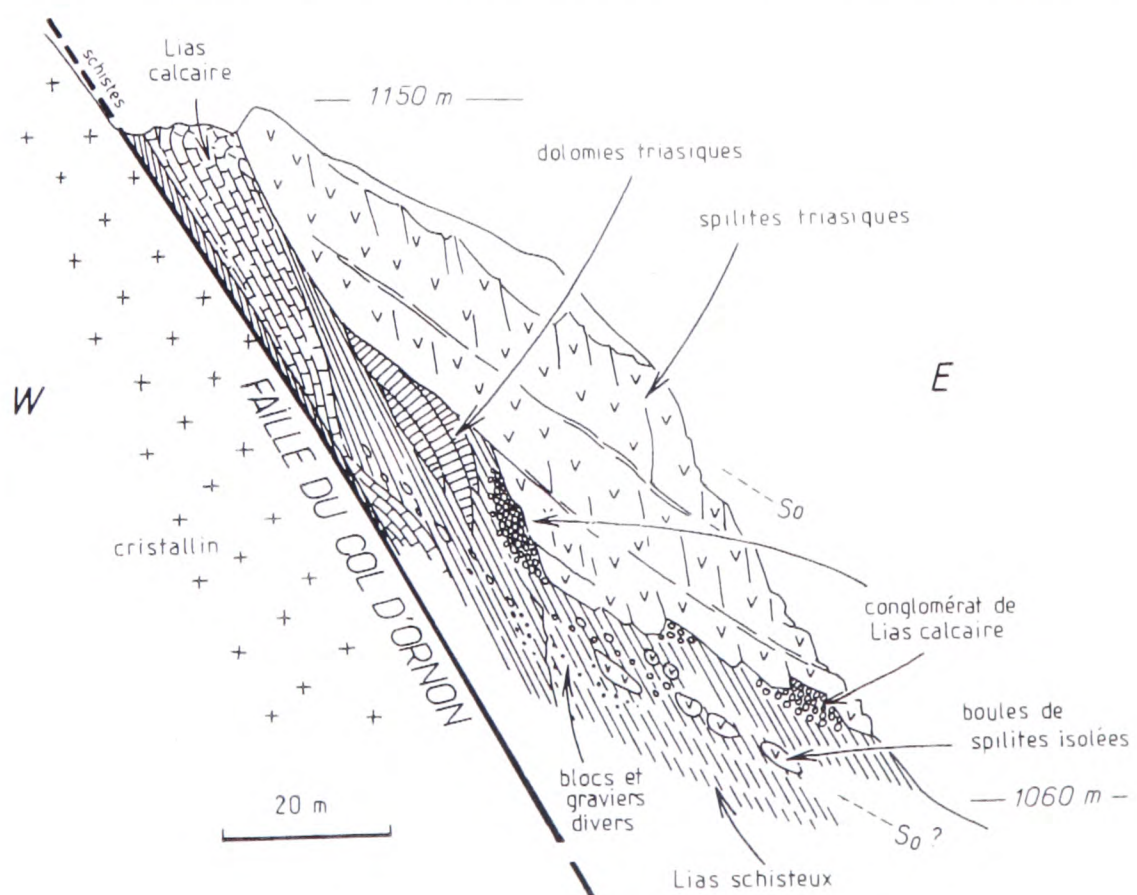


Figure 8.7b Olistoliths adjacent to the Ornon fault near la Chalp (from Barféty & Gidon, 1984)

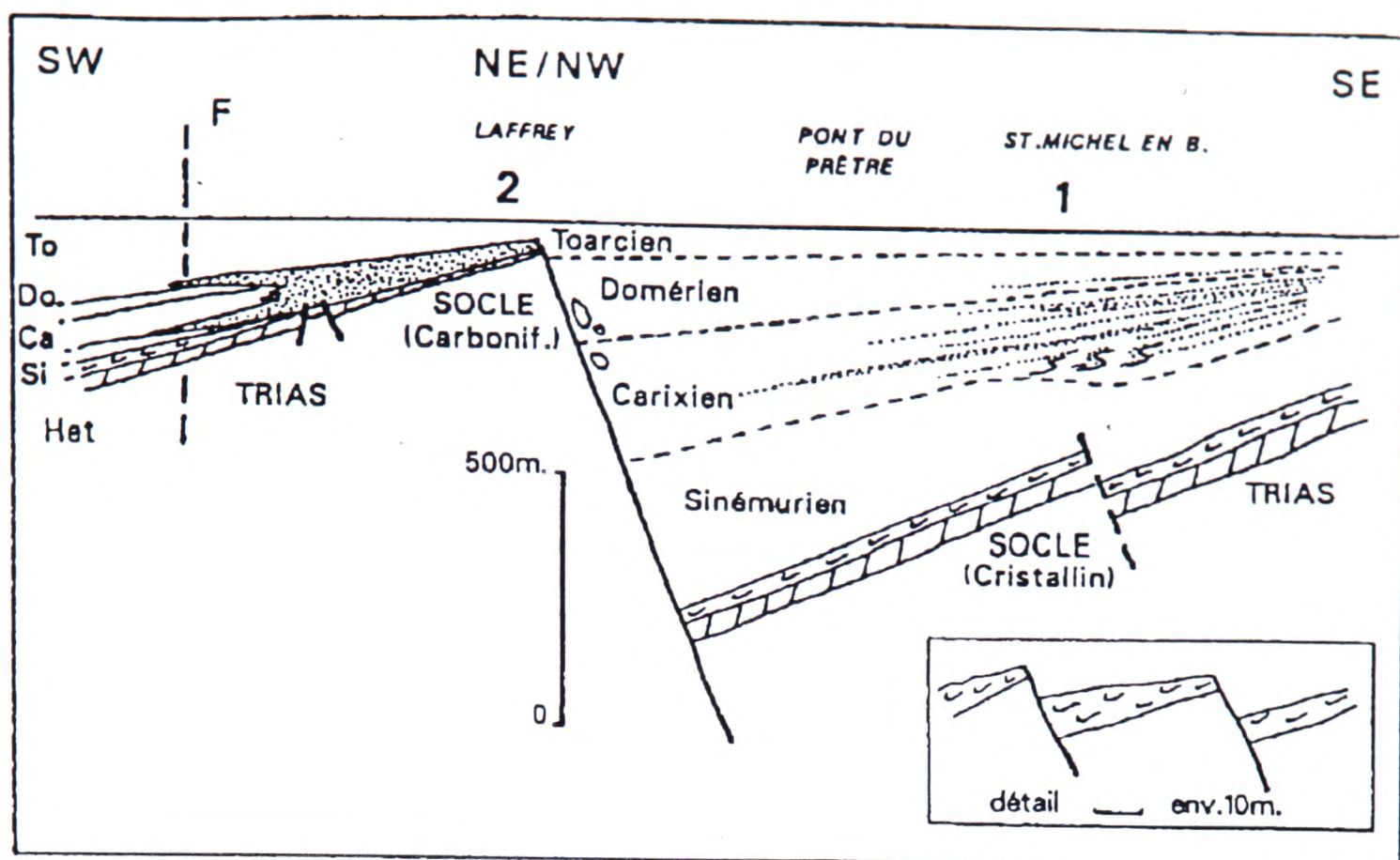


Figure 8.8a Reconstruction of the western half-graben showing interpreted relationships of the Laffrey, Pont du Prêtre and St. Michael en Beaumont sections discussed in text (from Bas, 1985)



Figure 8.8b Facies of the Pont du Prêtre section: "Sinemurian-Lotharingian" limestone-marl alternations



Figure 8.9a Facies of the Pont du Prêtre section: "Lotharingian" thick-bedded limestones



Figure 8.9b Facies of the Pont du Prêtre section: "Carixian" limestone-marl alternations



Figure 8.9c Facies of the Pont du Prêtre section: "Domerian" thick-bedded limestones without marls



Figure 8.10a Facies of the St Michael en Beaumont section: Unit D, limestone-marl interbeds

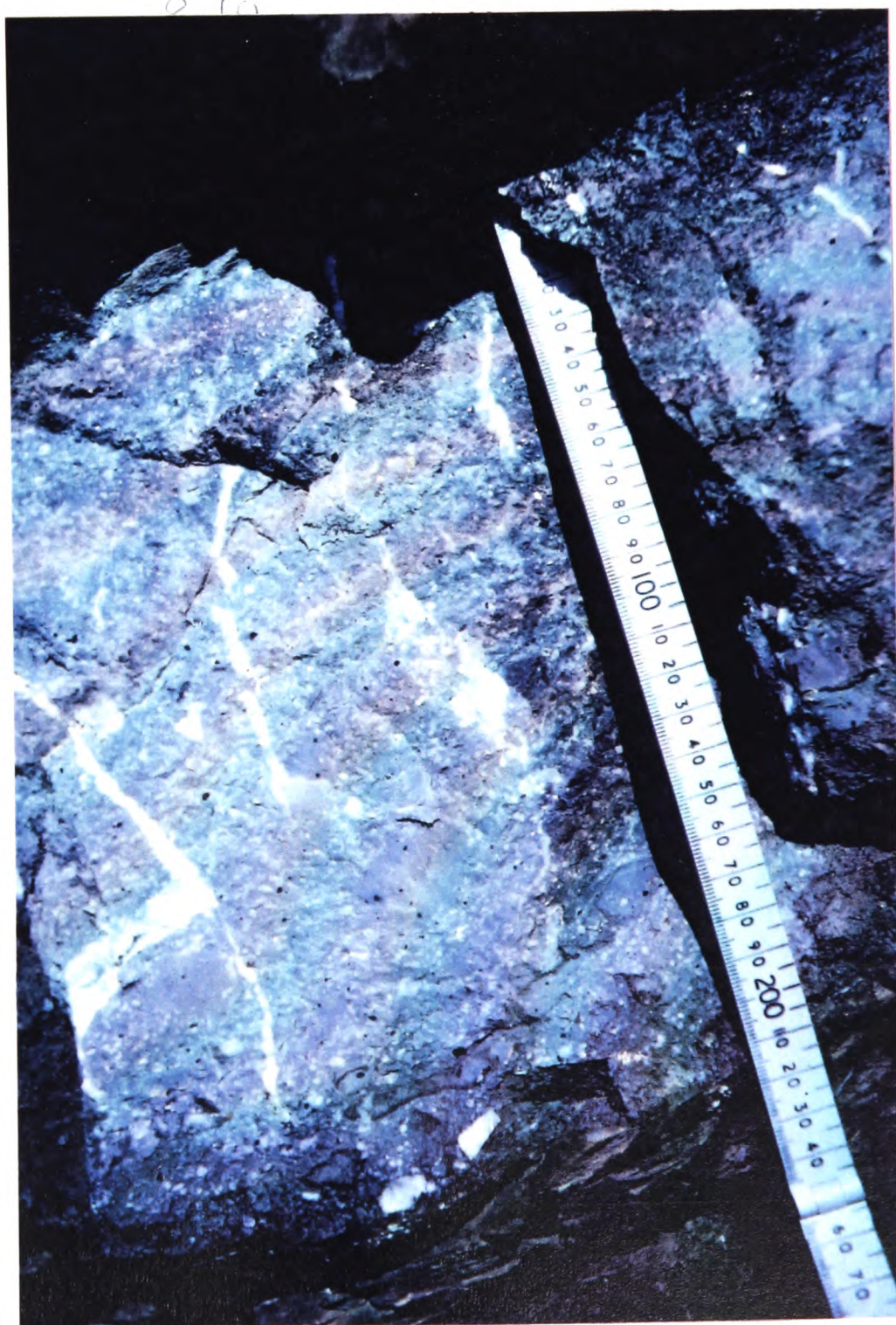


Figure 8.10b Facies of the St Michael en Beaumont section: Unit D, detail of crinoidal grainstone bed



Figure 8.11a Facies of the St Michael en Beaumont section: Unit F, massive grainstones

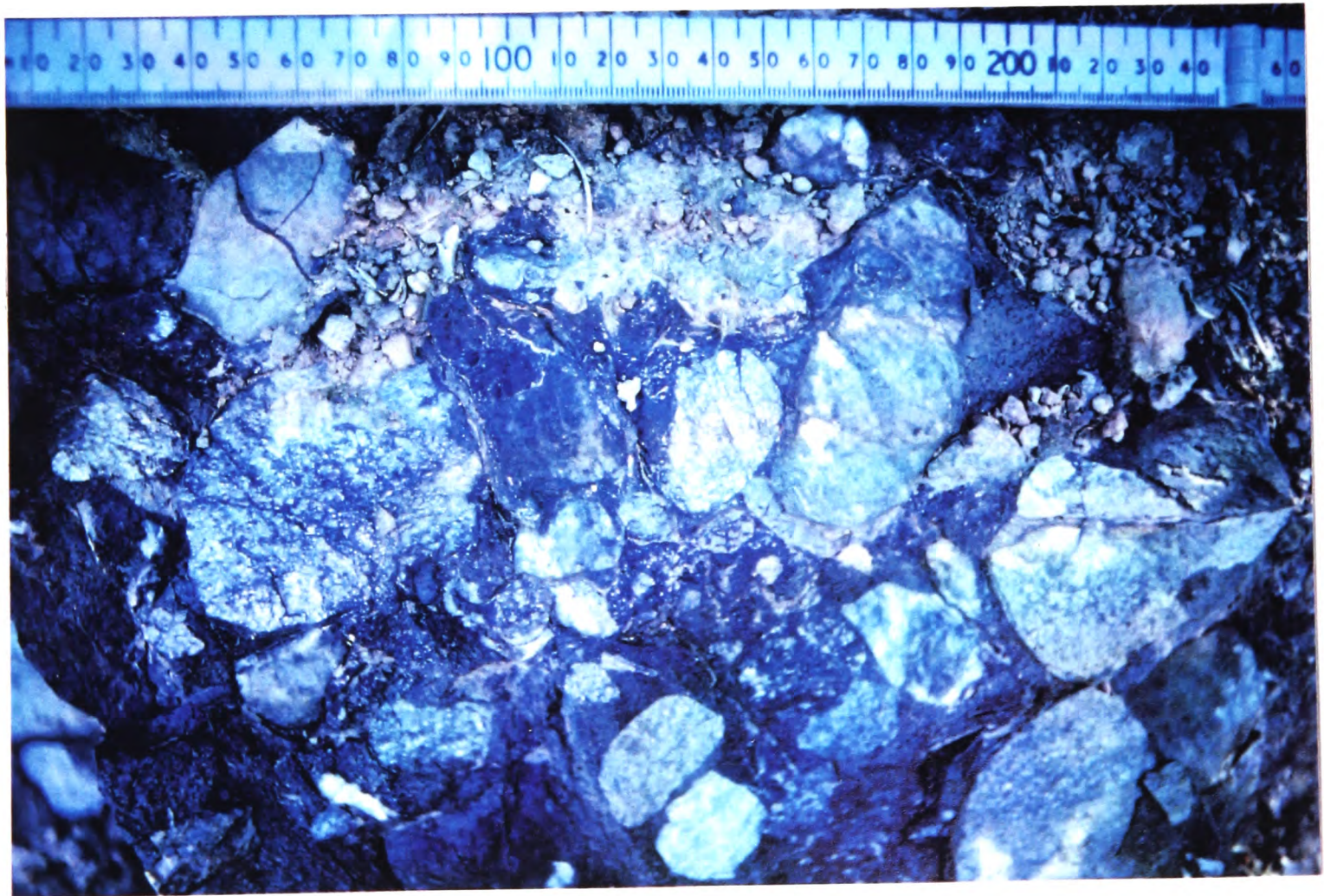


Figure 8.11b Facies of the St Michael en Beaumont section: Unit G, detail of cobble bed

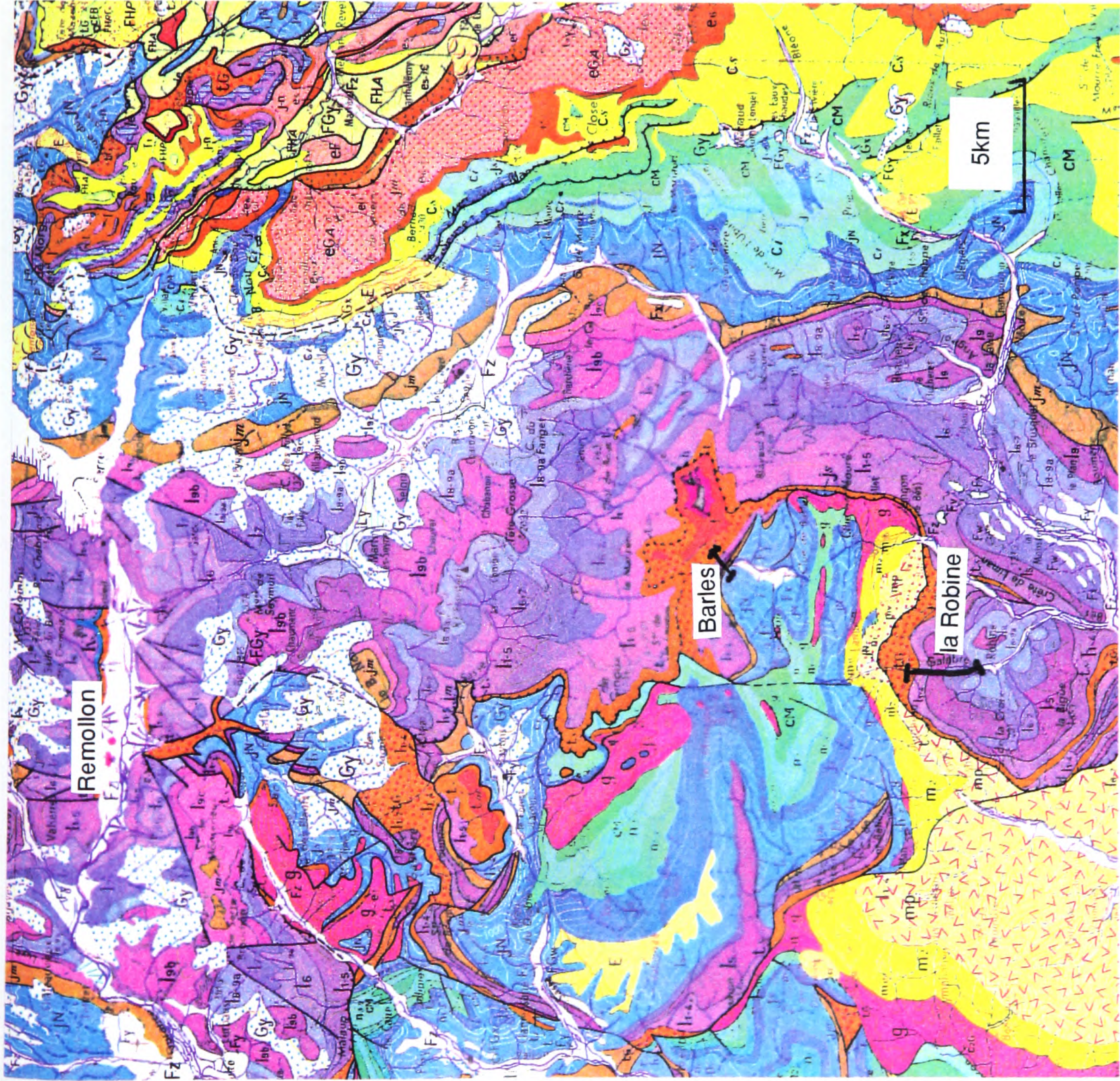


Figure 8.12a Locality map for the area north of Digne (from Carte Géologique de la France, 1:250,000, Gap Sheet). Note the thrust which separates the autochthonous Barles section from the allochthonous la Robine and Remollon sections

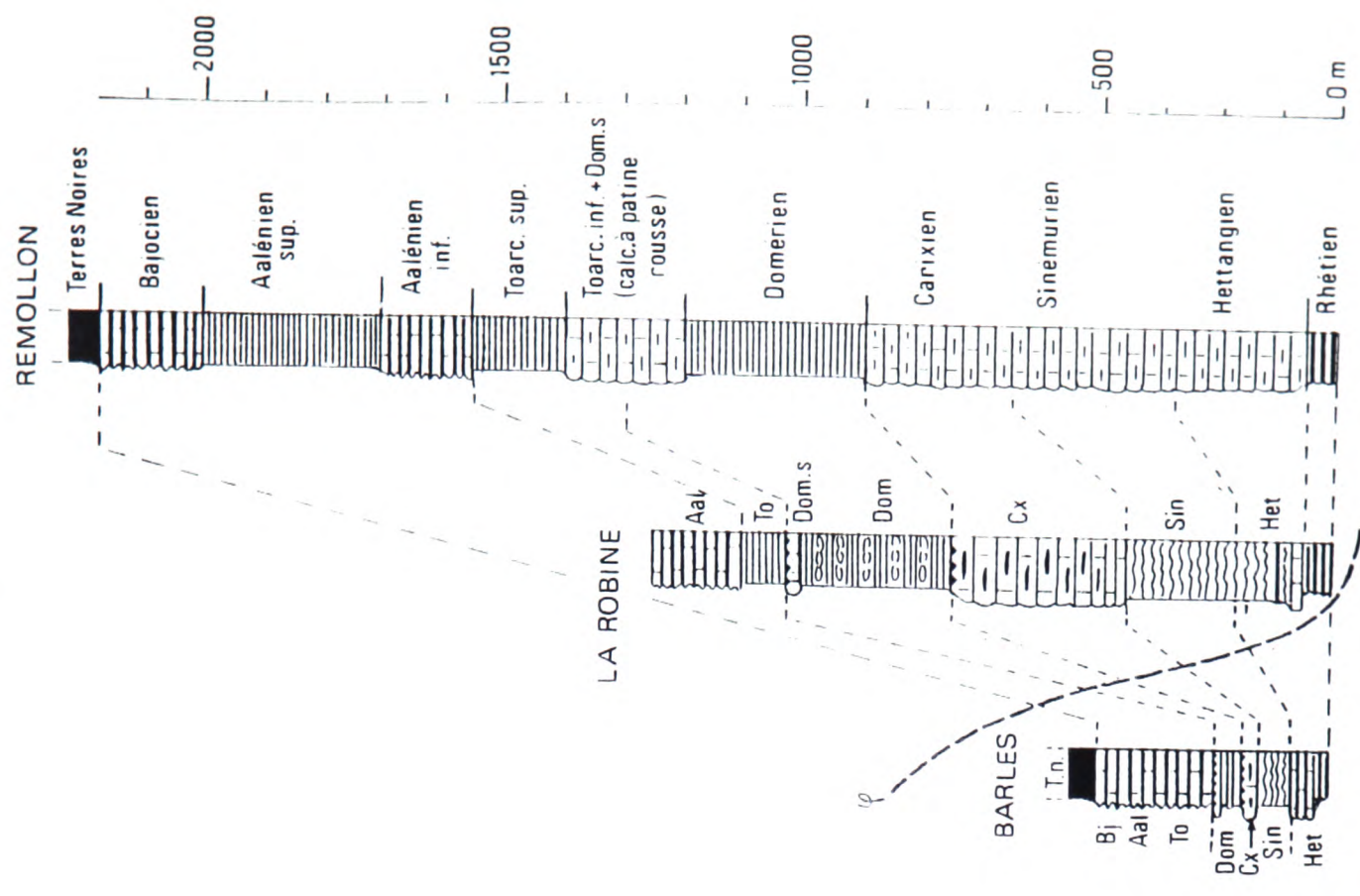


Figure 8.12b Logs of the Barles, la Robine and Remollon sections (from Debelman, 1983)



Figure 8.13a The Barles section: "Rhaetian-Hettangian", thick fine-grained limestones interbedded with cm-bedded intervals.



Figure 8.13b The Barles section: "Lotharingian", blocky, siliceous limestones

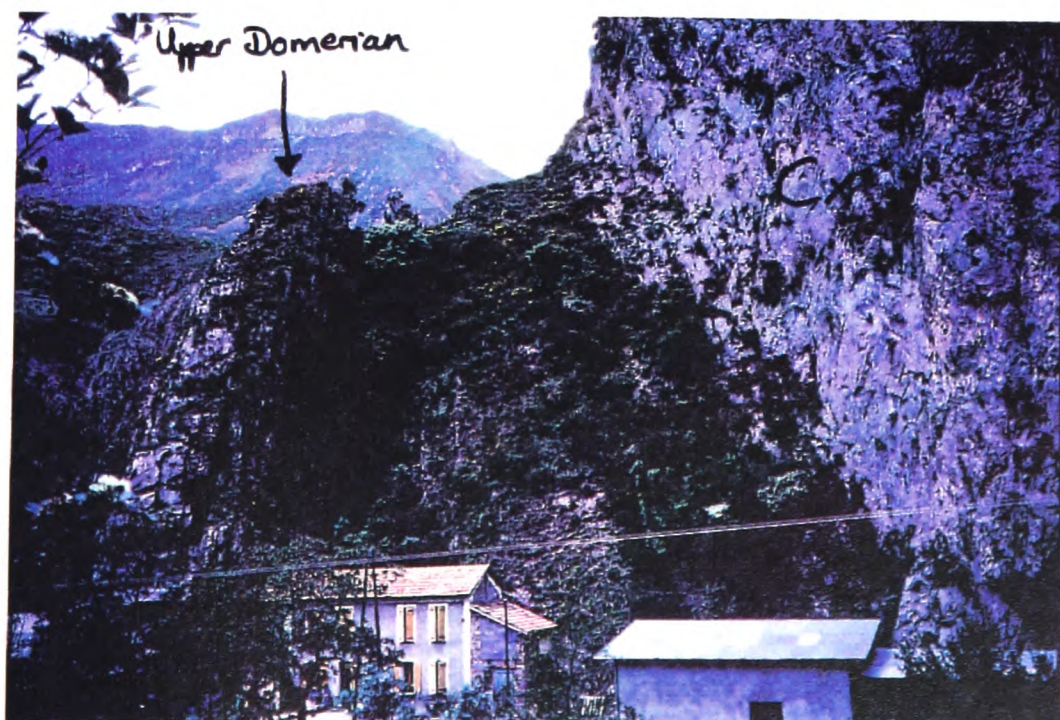


Figure 8.13c The Barles section: major "Carixian" limestone on right, Domerian marls centre and latest Domerian limestone on left

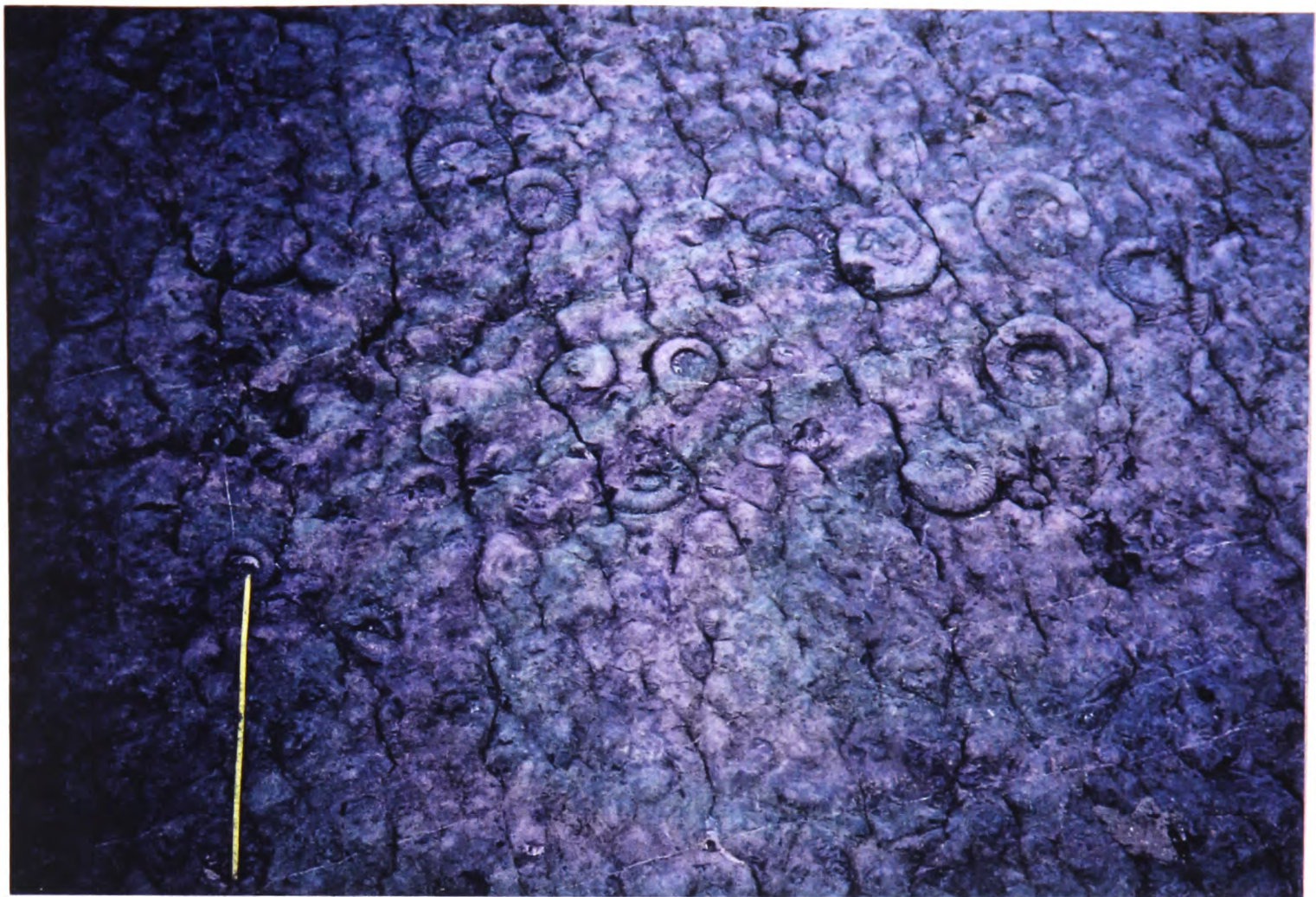


Figure 8.14a Fossil concentration within the *semicostatum* Zone, la Robine

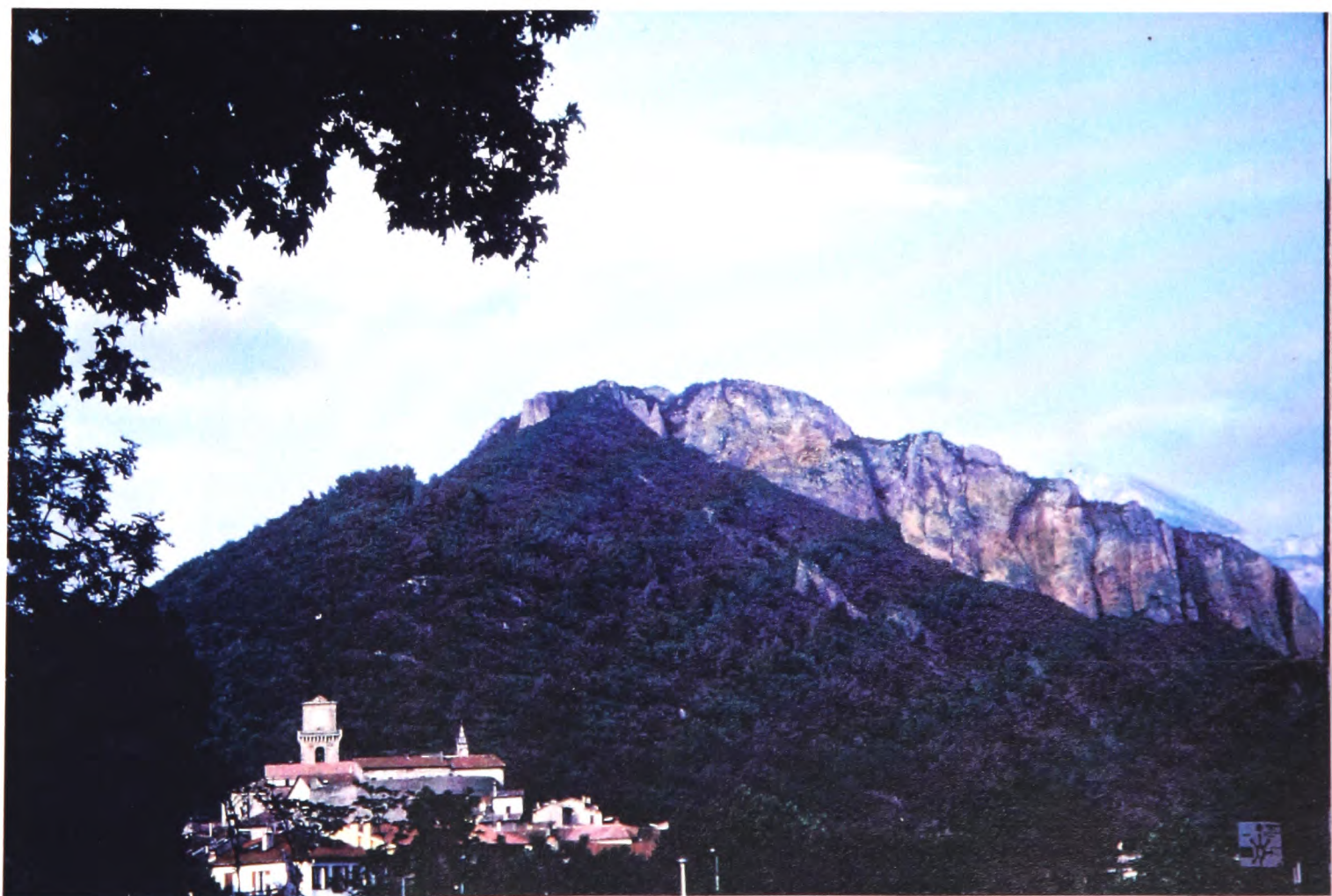


Figure 8.14b The Lotharingian-Carixian limestone which forms a major landscape feature around the town of Digne



Figure 8.15a La Robine. Foreground: Domesian marls capped by late Domesian limestone. Background: Toarcian marls



Figure 8.15b Domesian limestone overlain by Toarcian marls. The mid-Toarcian limestone is arrowed: locally this rests directly on the Domesian with pinchout of the intervening marls.

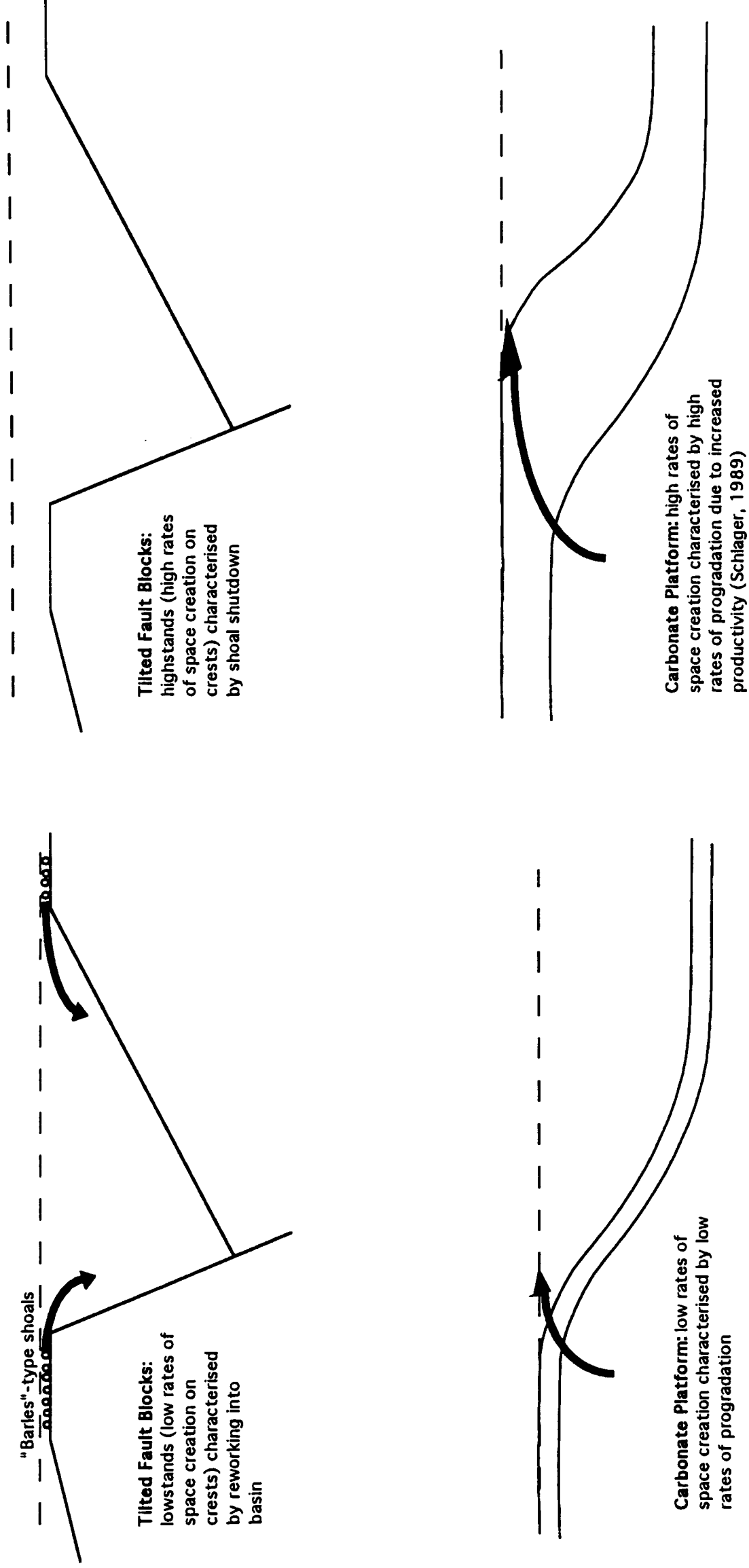


Figure 8.16 Response of half-graben and carbonate platform systems to changing base level

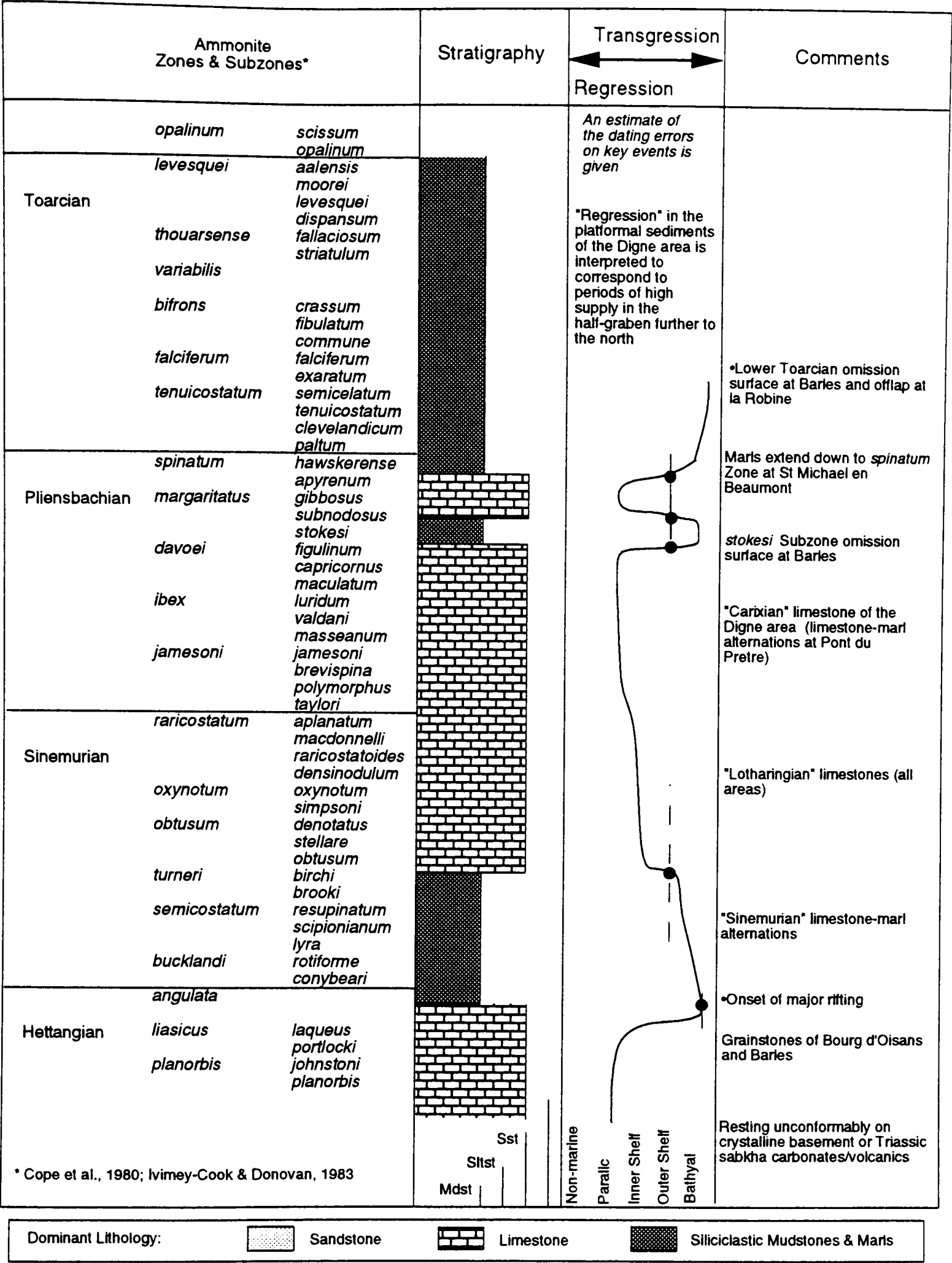


Figure 8.17 Summary of stratigraphic events in the Lower Jurassic of the Western Alps

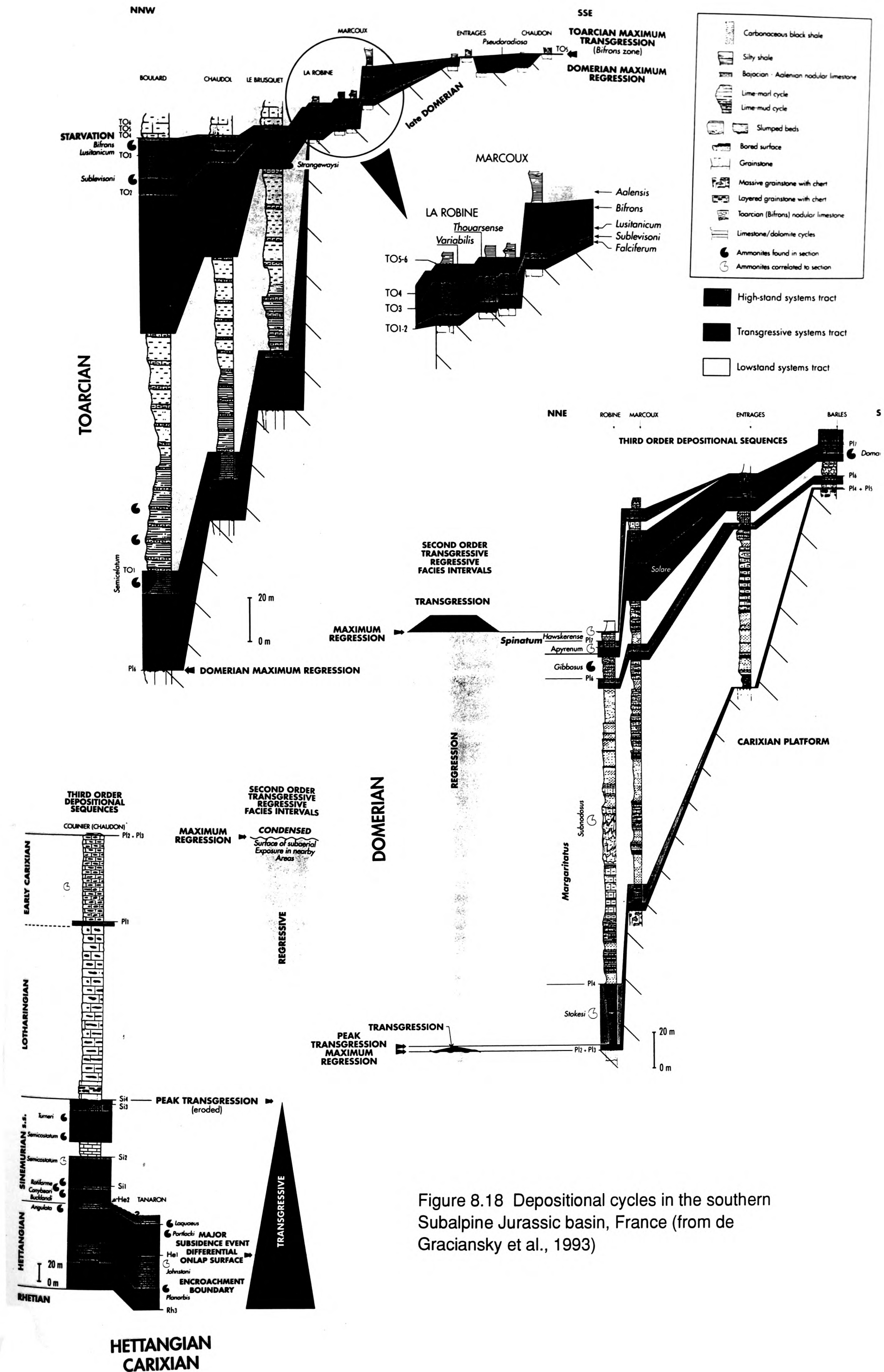


Figure 8.18 Depositional cycles in the southern Subalpine Jurassic basin, France (from de Graciansky et al., 1993)

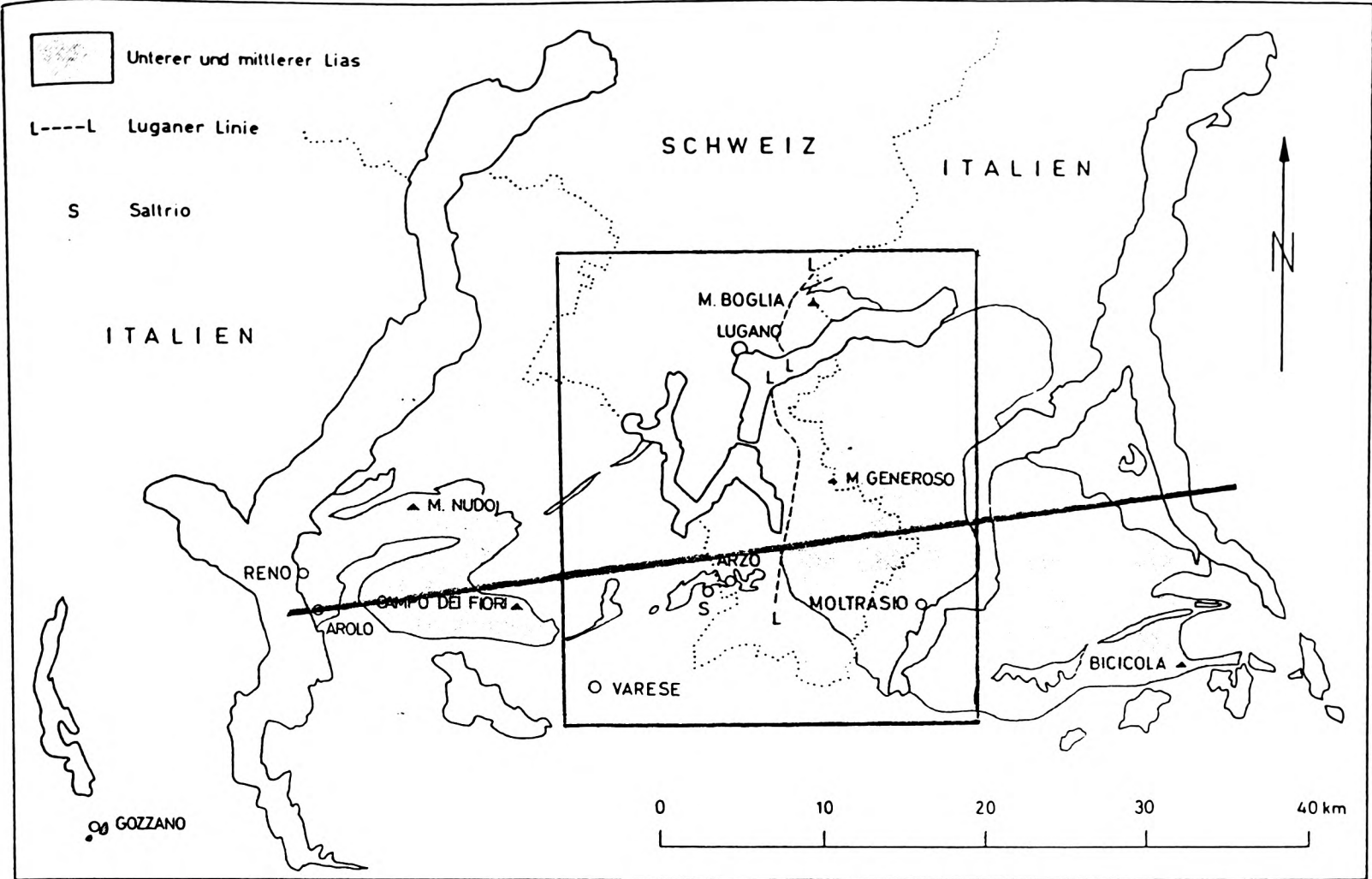


Figure 9.1a Outcrop of the Lower and Middle Lias in Western Lombardy (from Bernoulli, 1964)

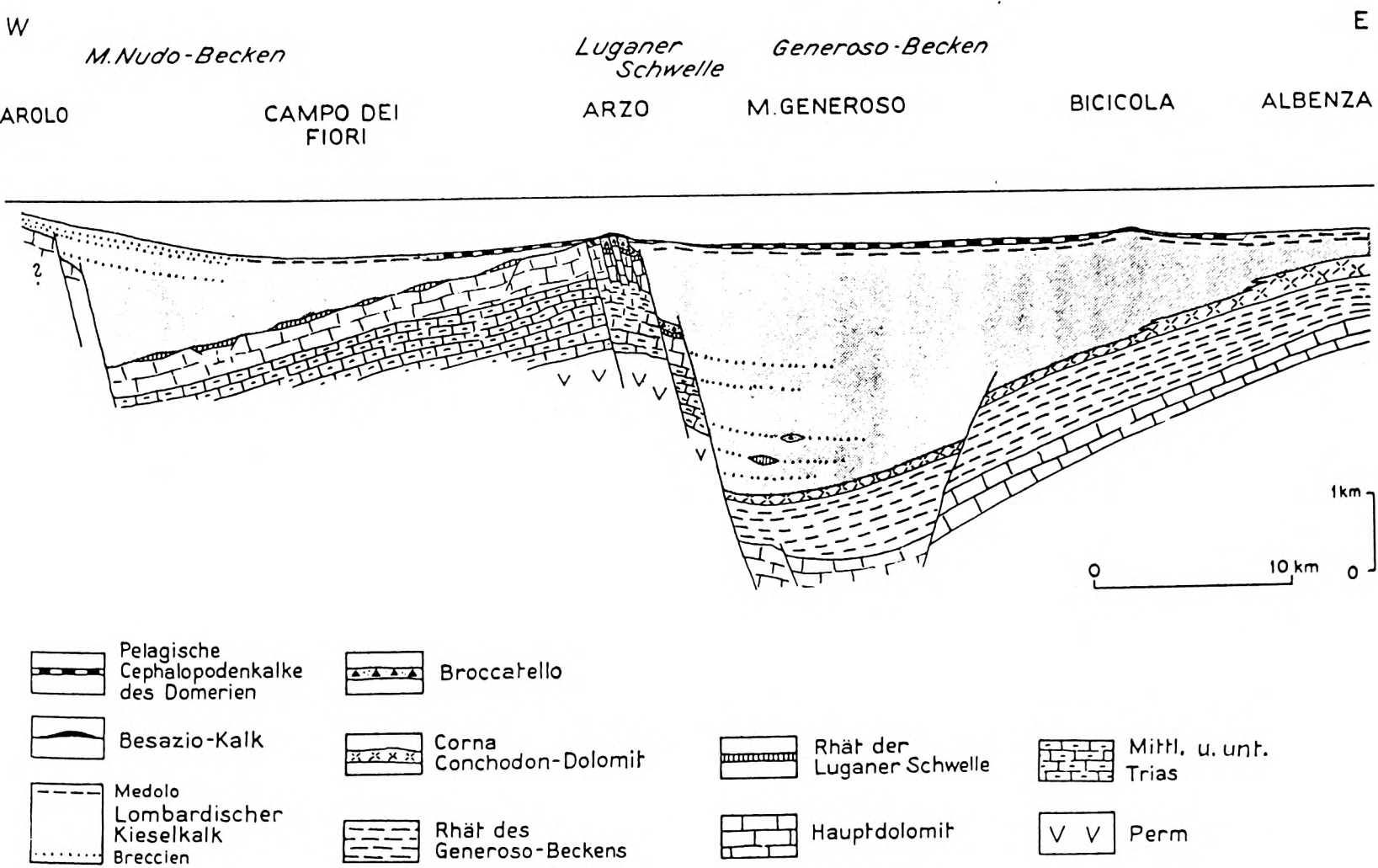


Figure 9.1b Restored cross-section of the Monte-Nudo and Monte Generoso half-graben (from Bernoulli, 1964)

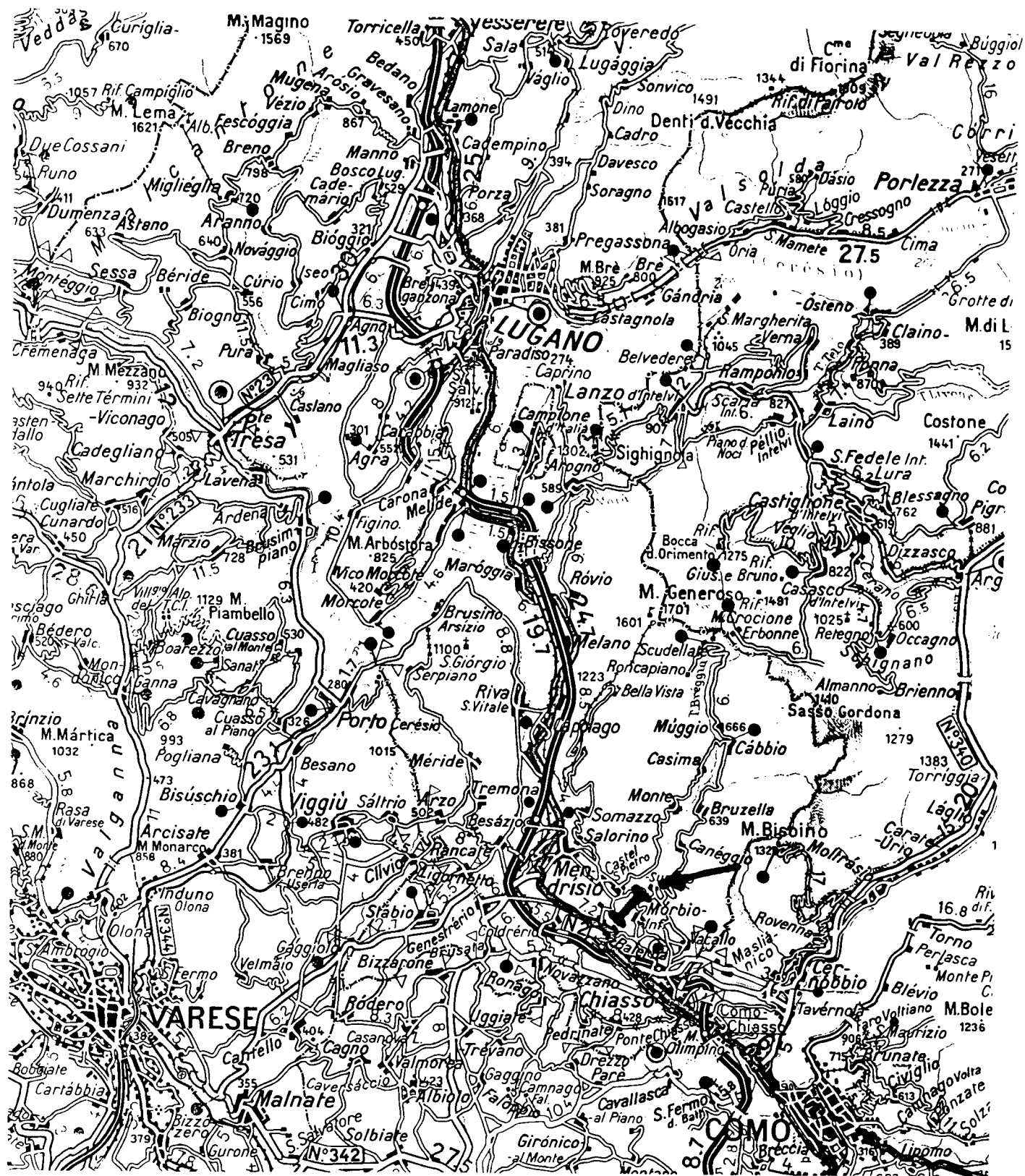


Figure 9.2 Location map for the Breggia Gorge: studied section is arrowed



Figure 9.3a Facies of the Lower Jurassic, Breggia Gorge: limestone-marl interbeds of the Lombardische Kieselkalk

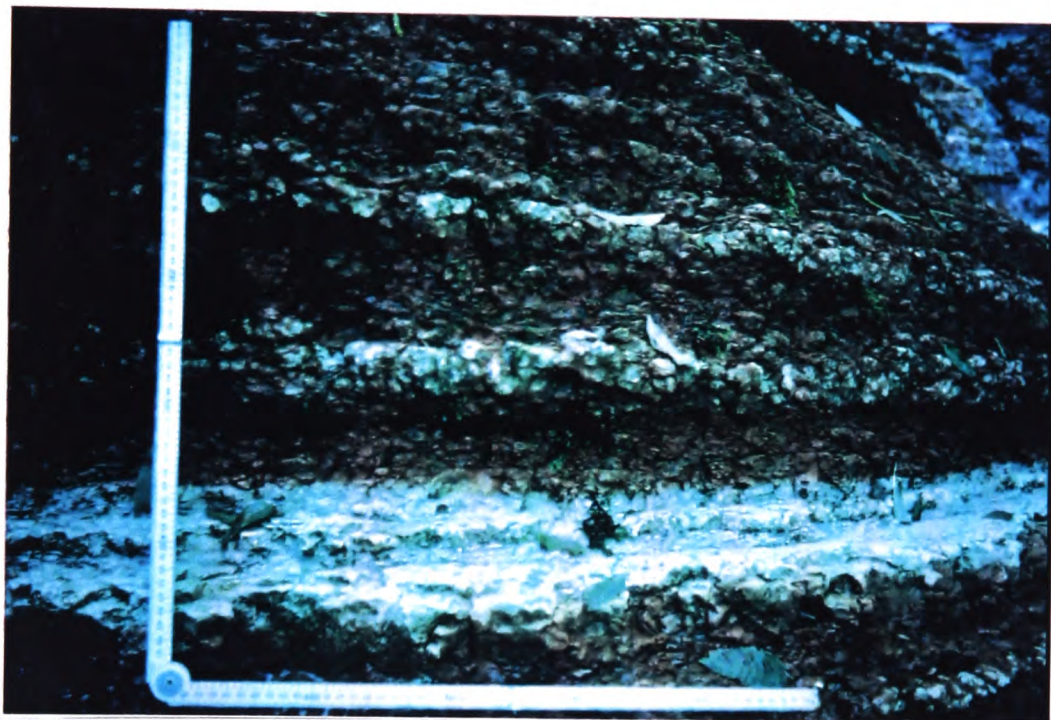


Figure 9.3b Facies of the Lower Jurassic, Breggia Gorge: Lower Toarcian red mudrocks



Figure 9.3c Facies of the Lower Jurassic, Breggia Gorge: Upper Toarcian nodular limestones and red marls

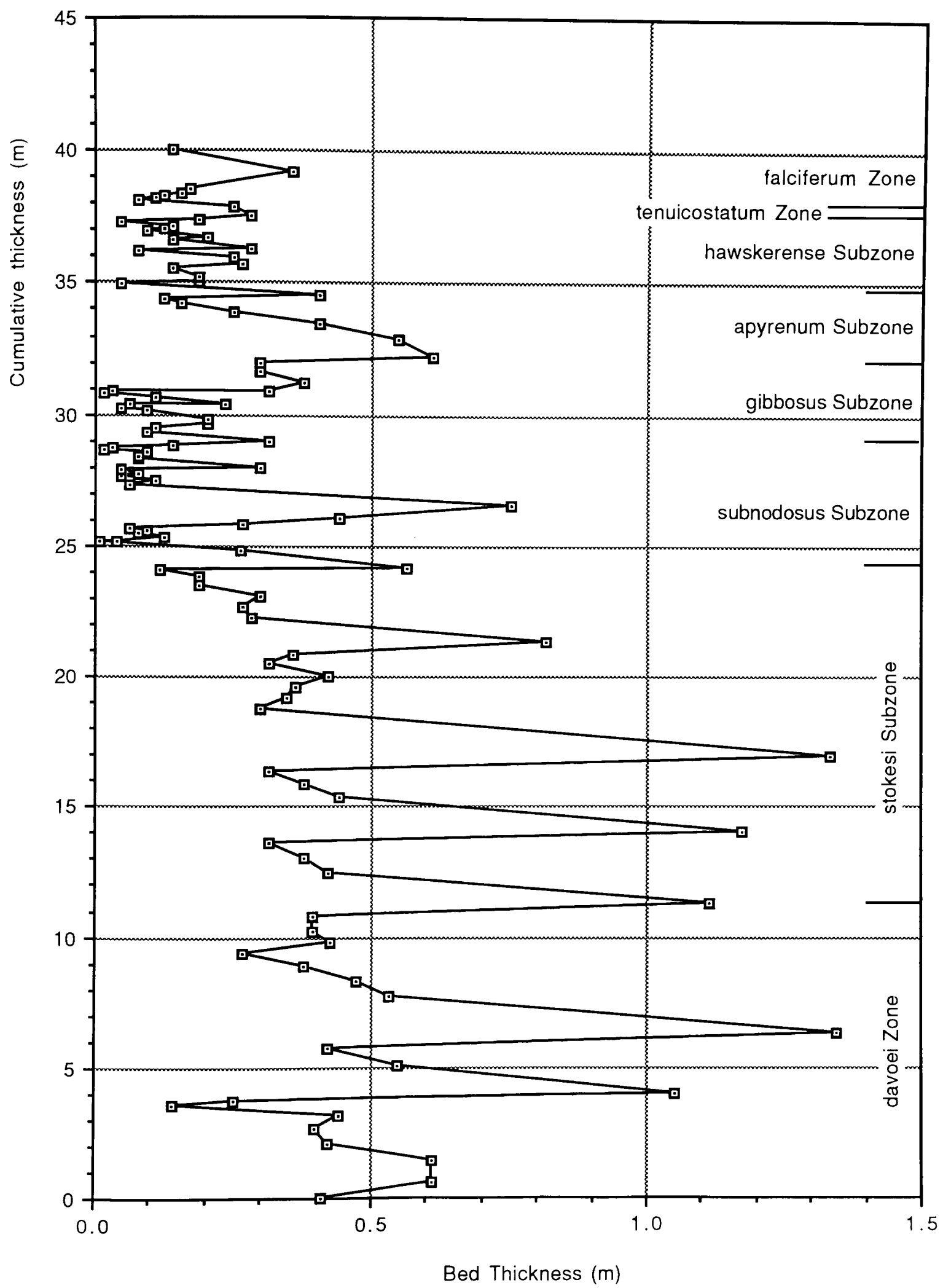


Figure 9.4 Bed thickness data for the Breggia Gorge (based on log of Wiedenmayer, 1980)

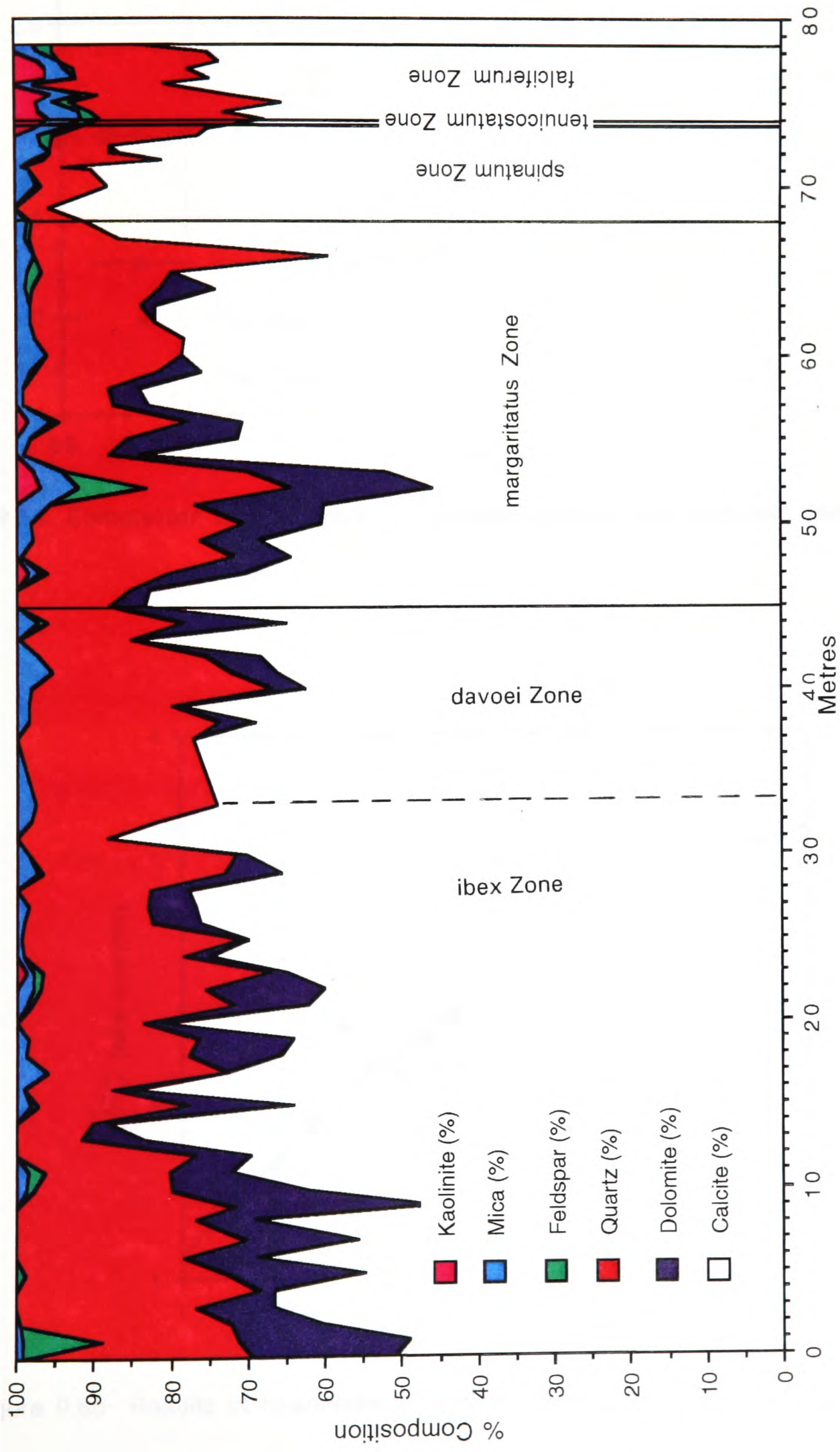


Figure 9.5 Whole-rock XRD data: Breggia Gorge

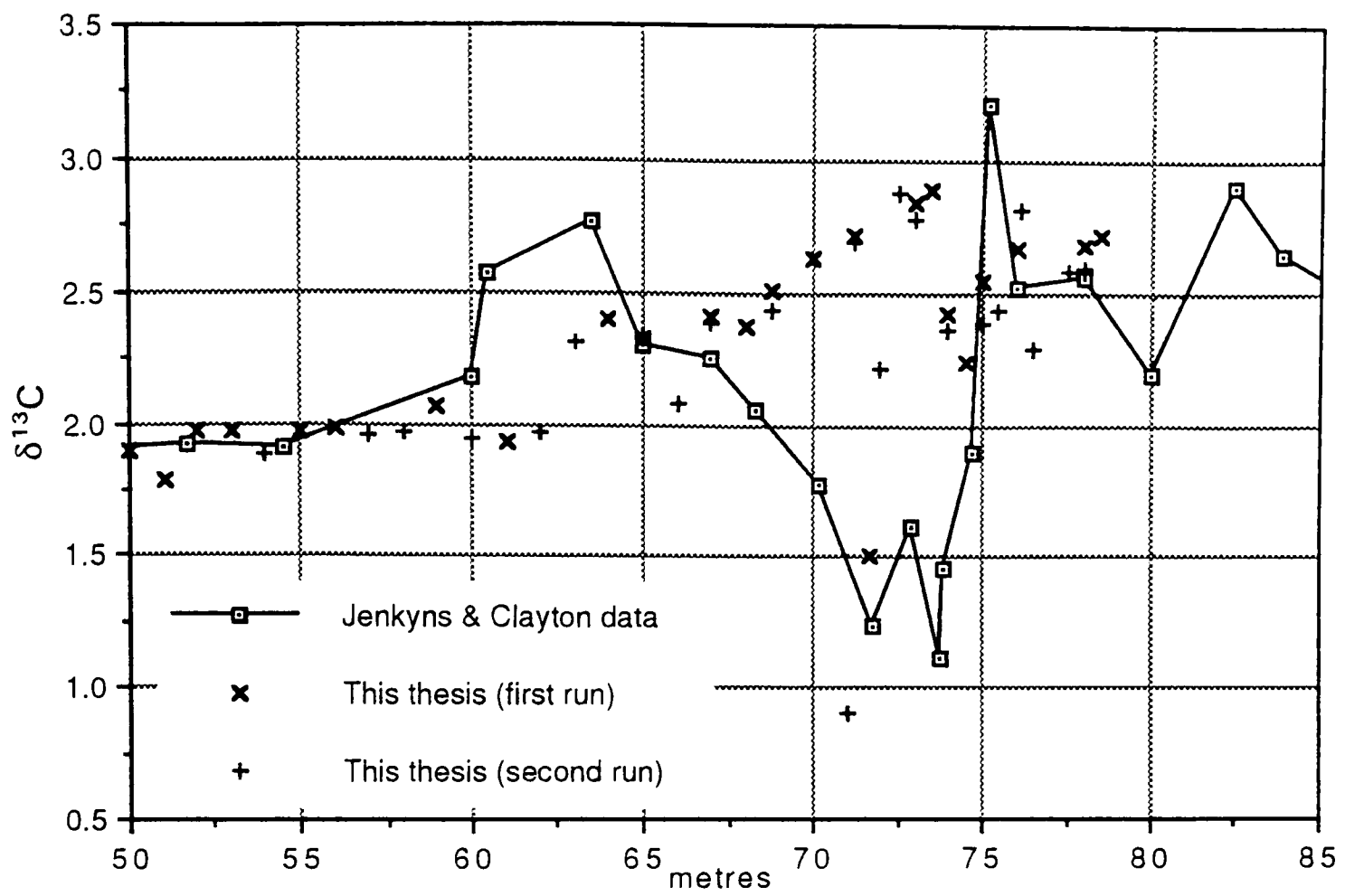


Figure 9.6a Comparison of whole-rock $\delta^{13}\text{C}$ measurements: this work and Jenkyns & Clayton (1986)

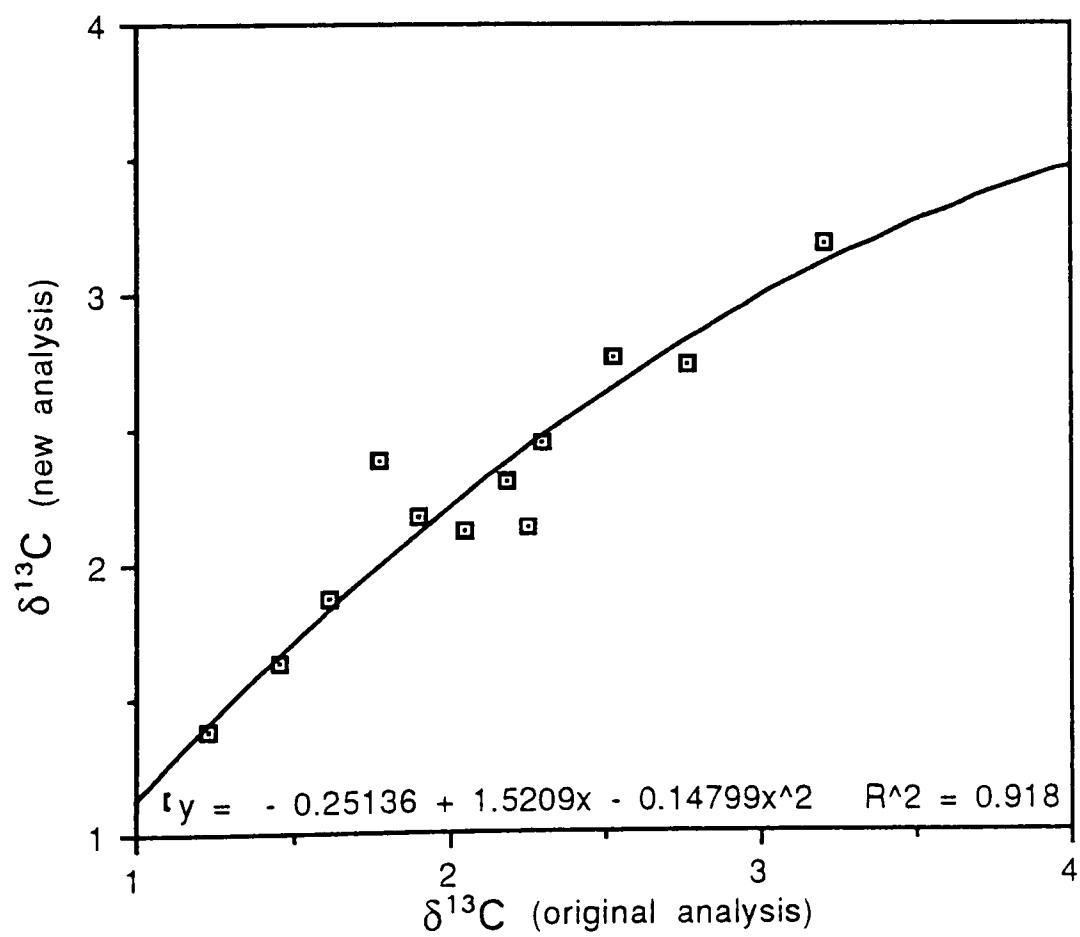


Figure 9.6b Results of re-analysis of original material used by Jenkyns & Clayton (1986)

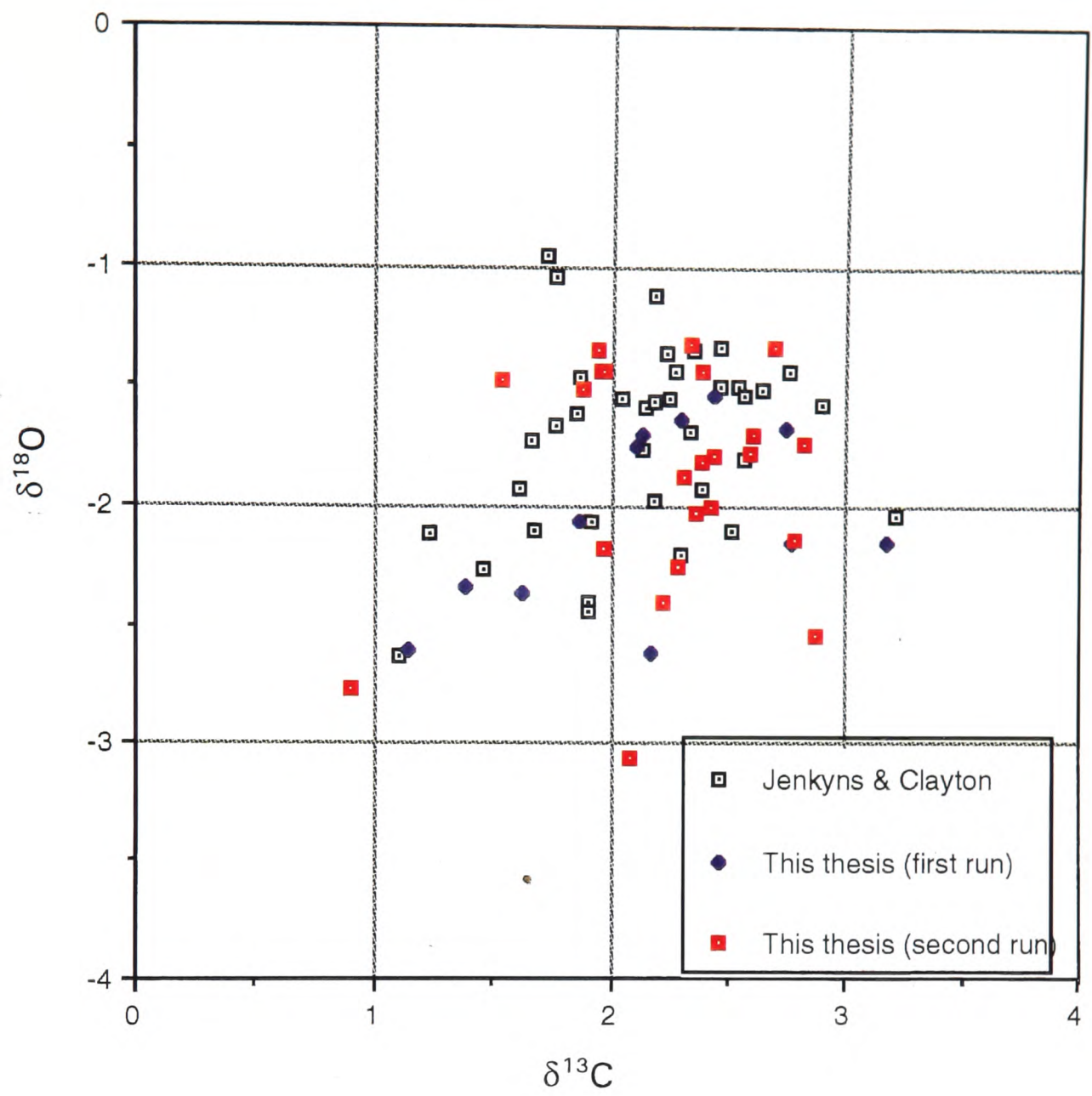


Figure 9.7 $\delta^{13}\text{C}/\delta^{18}\text{O}$ cross-plot: data from this thesis and Jenkyns & Clayton (1976)

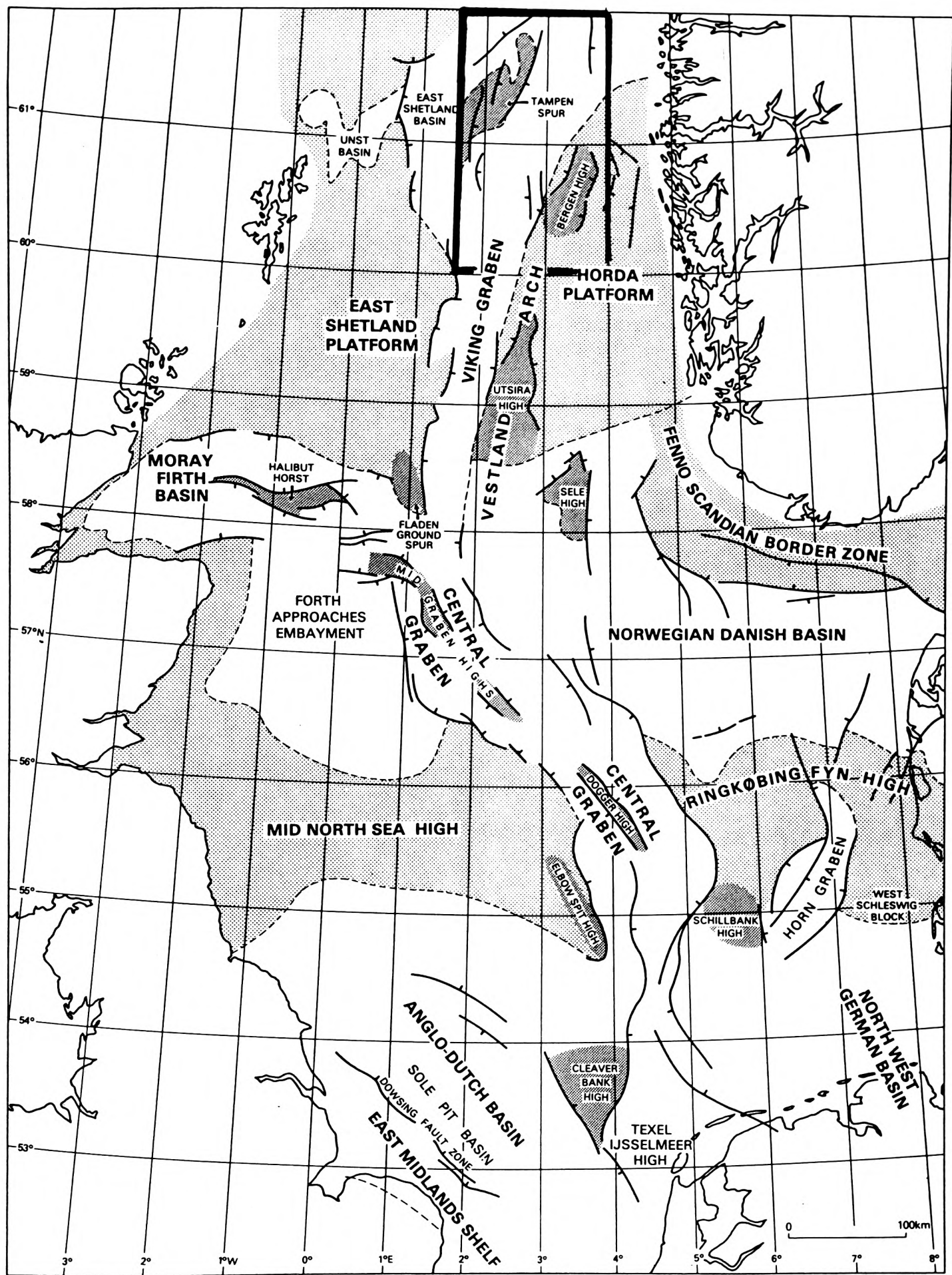


Figure 10.1 The North Sea Rifts (from Day et. al, 1981) showing location of study area

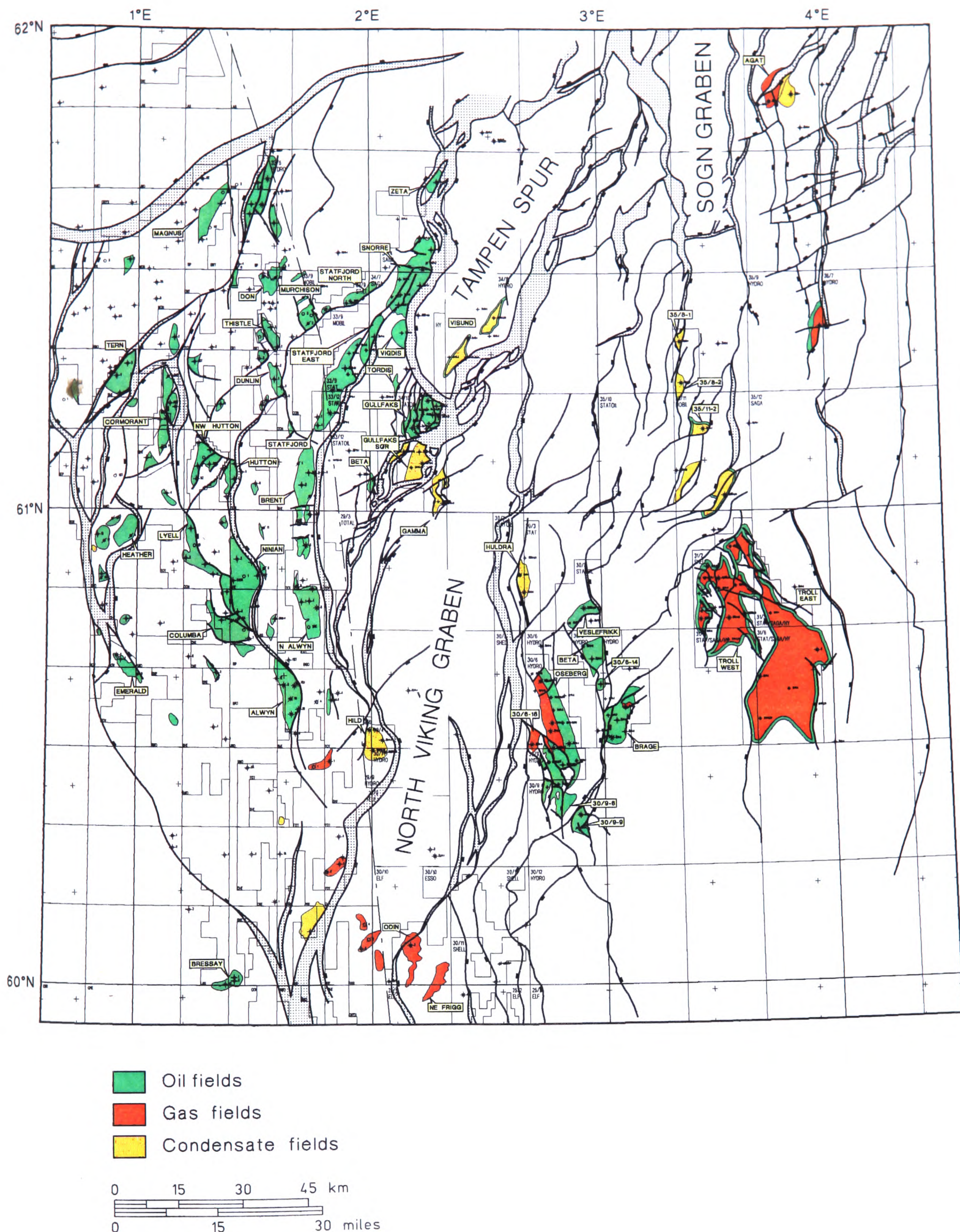


Figure 10.2 North Viking Graben structural elements

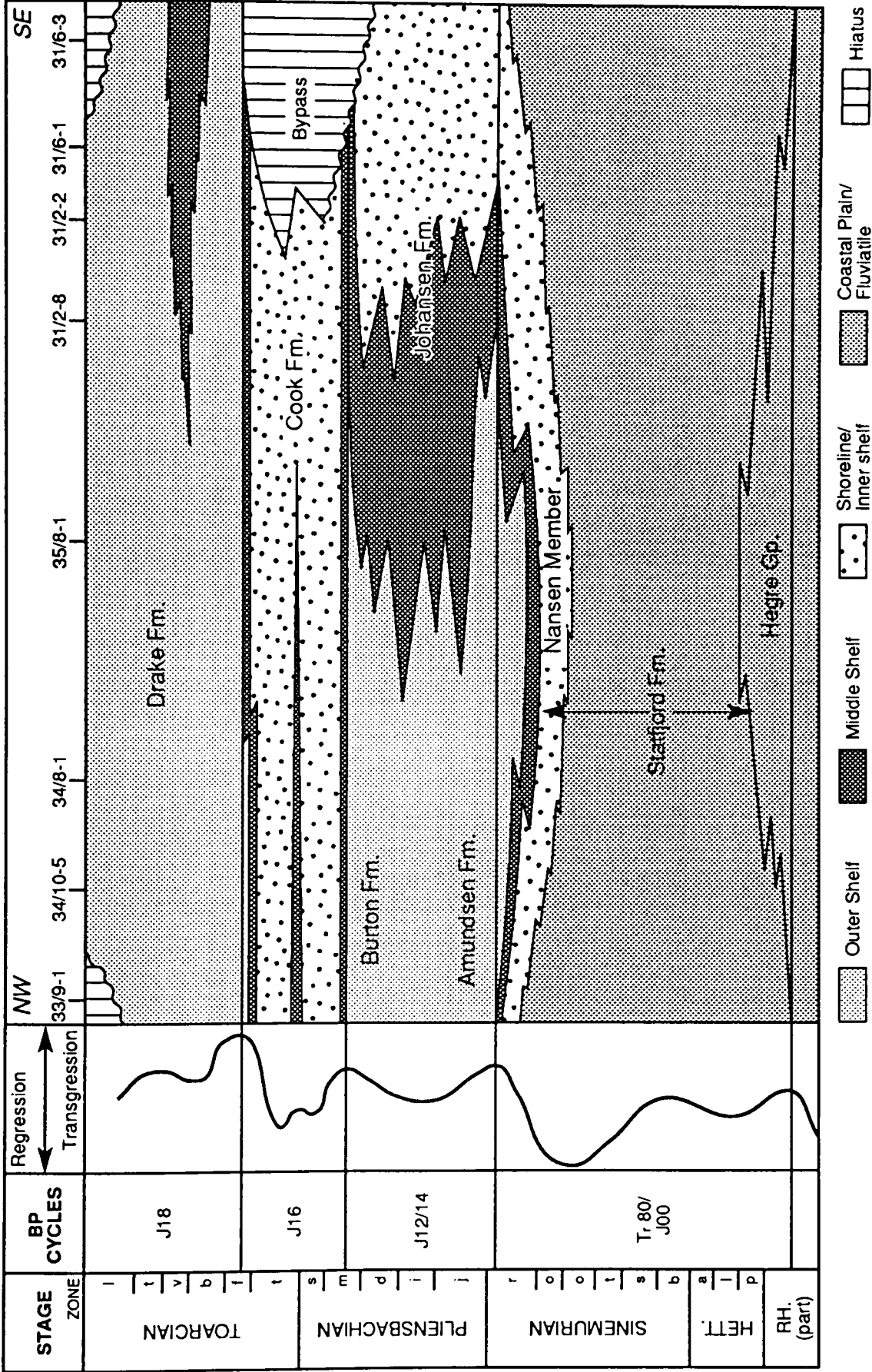


Figure 10.3 Summary of lithostratigraphic nomenclature (from Parkinson & Hines, in press)

Tool	Principle	Units	Lithological response	Pitfalls
Gamma-ray	Natural rock radioactivity measured using scintillation counter	API (arbitrary units defined with respect to a reference well at the University of Houston)	Responds to Th, K and U, concentrated in mudrocks and used, therefore, as a shale indicator.	Th, K and U also sited in feldspars, heavy minerals and (in the case of U) organic matter. See Appendix 1 for extended discussion.
Sonic	Measures travel time of a sound pulse between two points on the logging tool (sound travels faster through rock than borehole fluids)	$\mu\text{s}/\text{foot}$	Pore fluids are slower than rock, hence rocks with high porosity tend to be slower. Sandstones <u>tend</u> to be faster than shales. Carbonates fast, coals slow.	Considerable overlap in lithological properties.
Density	Measures number of lower-energy gamma-rays returned by Compton scattering when formation is bombarded with gamma-rays of medium energy.	Number of returned gamma-rays inversly proportional to electron density, which is closely related to common density. Results computed and expressed as g/cm^3	Density is a function of lithology and porosity.	
Neutron	Formation is bombarded with fast neutrons. The number of these which are absorbed rather than reaching a detector is a measure of the density of hydrogen nuclei in the formation.	Hydrogen nuclei reside in pore space (water, oil or gas). Tool is therefore a measure of porosity expressed an neutron porosity units (NPHI), which relate to the response of the tool in water-saturated clean limestones	An alternative measure of porosity such that it is a powerful indicator of lithology when used in combination with the density tool (see text for discussion)	Sensitive to free and bound water: shales and shaly sandstones give very variable responses.

Figure 10.4 Summary of wireline log responses

Well	API Cut-off	Well	API Cut-off
34/10-11	85	30/10-19	Values overlap
34/10-9	80-85	34/10-9	60
34/10-7	65	34/10-7	65
34/2-2	75	34/10-3	>75
30/6-11	80-90	34/4-5	50
30/6-2	50	34/2-2	70
30/3-2	85		

Figure 10.5a Tabulation of API gamma-ray values of lithologies described as sandstone in core for various North Viking Graben wells

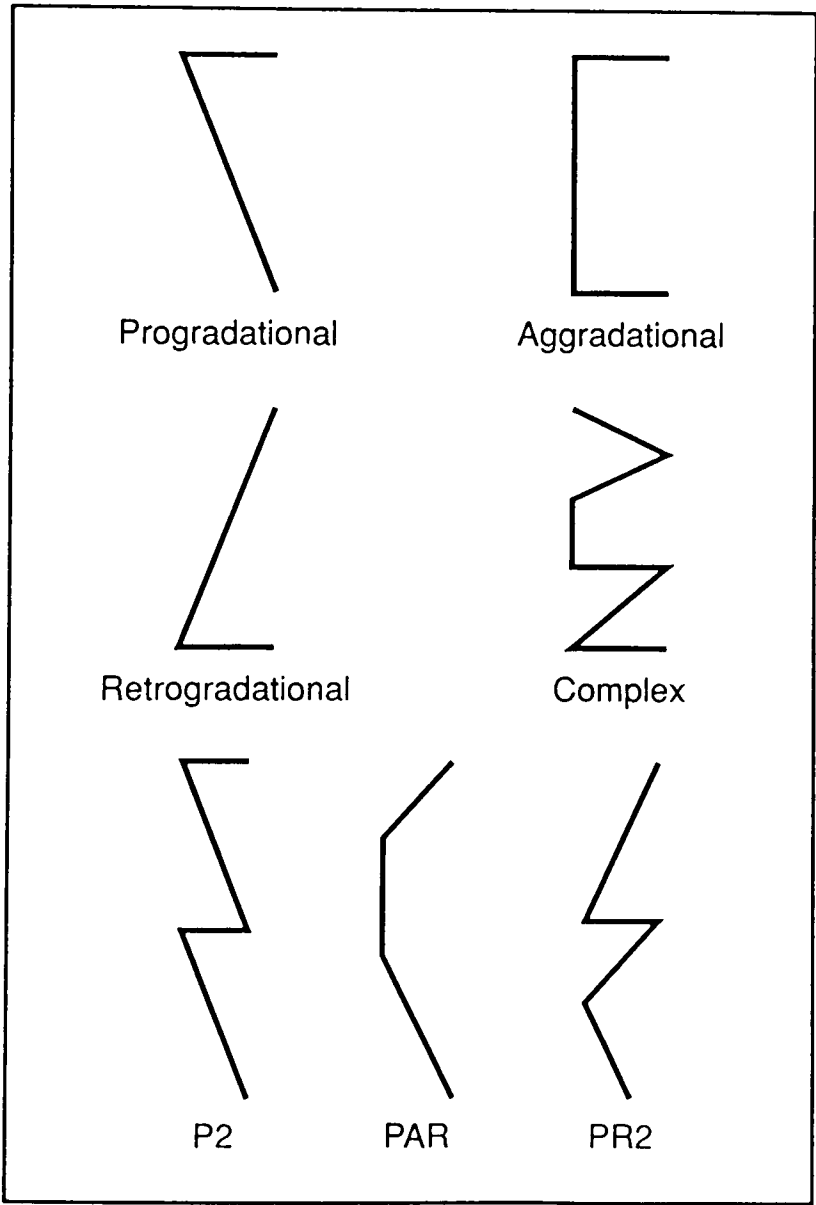


Figure 10.5b Summary of log-based facies scheme

	Well	Base Brent	Base J19	Base J18	J18/19 (m)	J18 Sst/Sh	J18 Sand (m)	J18/19 Facies	Base J16b	Base J16a	J16 (m)	J16 Sst/Sh	J16 Sand (m)	J16 Facies	Base J12 (m)	J12/14 (m)	J12/14 Sand	J12/14	J12/14 Facies
1	29/3-1	3913	ND	4045.000	132.000	0.000	0.000	A	ND	4213.000	168.000	0.036	6.000	P5+	4389.000	176.000	9.000	0.051	PR
2	29/6-1	4498	ND	4526.000	28.000	0.000	0.000	PR	ND	4612.000	86.000	0.198	17.000	PR	4728.000	116.000	28.000	0.241	PR
3	29/9-1	4422	ND	4482.000	60.000	0.000	0.000	A	ND	4557.000	75.000	0.440	33.000	PAR	4639.000	82.000	3.000	0.037	PR
4	30/2-1	3840	3850	3917.000	77.000	0.338	26.000	C	3963	4010.000	27.000	0.290	27.000	P2	4109.000	99.000	20.000	0.202	C
5	30/3-2	2950	2981	3027.000	77.000	0.429	33.000	P2	3072	3123.000	96.000	0.792	76.000	P2	3227.000	104.000	5.000	0.048	C
6	30/3-3	3110	3142	3188.000	78.000	0.179	14.000	P2	3234	3284.000	96.000	0.323	31.000	P2	3380.000	96.000	5.000	0.052	C
7	30/3-4	2962	2983	3030.000	68.000	0.206	14.000	PRP	3077	3132.000	102.000	0.667	68.000	P2	3232.000	100.000	36.000	0.360	PR
8	30/4-2	4062	4069	4113.000	51.000	0.000	0.000	PR	ND	4210.000	97.000	0.711	69.000	PR	4337.000	127.000	14.000	0.110	PR
9	30/6-1	2379	ND	2491.000	112.000	0.125	14.000	A	2537	2587.000	96.000	0.500	48.000	PA	2712.000	125.000	0.000	0.000	A
10	30/6-3	2513	ND	2637.000	124.000	0.000	0.000	C	2679	2764.000	127.000	0.543	69.000	A2	2884.000	120.000	0.000	0.000	C
11	30/6-4	2685	ND	2808.000	123.000	0.000	0.000	C	2853	2900.000	92.000	0.326	30.000	C			15.000	0.152	C
12	30/6-5	2957	2990	3023.000	66.000	0.030	0.000	PR	3071	3124.000	101.000	0.515	52.000	C	3223.000	99.000	0.000	0.000	C
13	30/6-8	3171	3199	3289.000	118.000	0.000	0.000	C	3345	3404.000	115.000	0.235	27.000	P2R	3528.000	124.000	0.000	0.000	C
14	30/6-11	3561	ND	3657.000	96.000	0.021	2.000	C	3728	3769.000	112.000	0.152	17.000	C	3893.000	124.000	0.000	0.000	PR
15	30/6-14	2589	2598	2648.000	59.000	0.322	19.000	PRP	2677	2714.000	66.000	0.333	22.000	PC	2783.000	69.000	21.000	0.304	C
16	30/7-7	ND	ND	4732.000	ND	0.000	0.000	C	ND	4803.000	71.000	0.535	38.000	PC	4883.000	80.000	2.000	0.025	P
17	30/9-4	3631	ND	3755.000	124.000	0.000	0.000	A	ND	3882.000	125.000	0.000	0.000	C	4170.000	288.000	14.000	0.049	C
18	30/9-5	2253	ND	2319.000	66.000	0.000	0.000	C	2380	2444.000	137.000	0.360	45.000	C	2604.000	160.000	14.000	0.087	A
19	30/11-3	4020	4104	4185.000	165.000	0.139	23.000	C	ND	4322.000	137.000	0.204	28.000	PR	4647.000	325.000	0.000	0.000	PA
20	31/2-1	1984	1991	2063.000	79.000	0.101	8.000	?	2086	2174.000	111.000	0.342	38.000	P2	2290.000	116.000	88.000	0.759	PR
21	31/2-2	ND	2073	2144.000	71.000	0.197	14.000	P	2159	2216.000	72.000	0.556	40.000	P2	2360.000	144.000	105.000	0.729	PR
22	31/2-3	ND	1916	2008.000	92.000	0.391	36.000	P	ND	2096.000	88.000	0.682	60.000	C	2232.000	136.000	100.000	0.735	PA
23	31/2-4	1907	ND	2006.000	99.000	0.071	7.000	PC	ND	2125.000	119.000	0.479	57.000	P2+	2248.000	123.000	83.000	0.675	PA
24	31/2-5	ND	2070	2172.000	102.000	0.235	24.000	PR	2200	2292.000	120.000	0.650	78.000	C	2403.000	111.000	93.000	0.838	PR
25	31/2-8	2720	ND	2778.000	58.000	0.000	0.000	C	ND	2864.000	186.000	0.489	91.000	PAP	3043.000	79.000	41.000	0.519	PA
26	31/3-1	1844	1851	1900.000	56.000	0.536	30.000	PR	Absent	1944.000	44.000	0.682	30.000	P	2117.000	173.000	170.000	0.983	PAC
27	31/3-3	2209	ND	2249.000	40.000	0.125	5.000	PR	ND	2291.000	42.000	0.048	2.000	P	2431.000	140.000	113.000	0.807	PAR
28	31/4-2	2368	2394	2436.000	68.000	0.000	0.000	C	2477	2558.000	122.000	0.213	26.000	C	2635.000	77.000	2.000	0.026	C
29	31/4-3	2413	2444	2496.000	83.000	0.229	19.000	P2	2543	2599.000	103.000	0.320	33.000	PC	2702.000	103.000	0.000	0.000	A
30	31/4-4	2798	2837	2879.000	81.000	0.025	2.000	C	2933	2982.000	103.000	0.592	61.000	P2	3087.000	105.000	23.000	0.219	C
31	31/4-5	2350	2395	2429.000	79.000	0.025	2.000	PRP	2482	2536.000	107.000	0.487	50.000	P2R	2645.000	109.000	3.000	0.028	PR
32	31/4-8	Eroded	2130	2178.000	48.000	0.000	0.000	C	2222	2255.000	77.000	0.429	33.000	PC	2345.000	90.000	0.000	0.000	A
33	31/5-2	2042	2053	2127.000	85.000	0.376	32.000	PA	2172	2223.000	96.000	0.354	34.000	PC	2336.000	113.000	109.000	0.965	C
34	31/6-1	1835	1850	1930.000	95.000	0.253	24.000	PR	1957	Absent	27.000	0.000	0.000	A	2109.000	152.000	138.000	0.908	PA
35	31/6-2	1974	1978	2045.000	71.000	0.099	7.000	P	Absent	Absent	0.000				2164.000	119.000	85.000	0.714	PA
36	31/6-3	1974	ND	2041.000	67.000	0.000	0.000	P	Absent	Absent	0.000				2142.000	101.000	81.000	0.822	PA
37	31/6-6	ND	ND	2077.000	ND	0.000	0.000	P	ND	2112.000	35.000	0.000	0.000	P	2222.000	110.000	68.000	0.618	PA
38	31/6-8	2061	ND	2124.000	63.000	0.000	0.000	P	ND	NP					NP				R
39	33/5-2	4291	4293	4313.000	22.000	0.000	0.000	PRP	4342	4380.000	67.000	0.179	12.000	PAP	4412.000	32.000	9.000	0.281	R
40	33/6-1	3622	ND	3695.000	73.000	0.000	0.000	C	ND	3754.000	59.000	0.000	0.000	PA	3790.000	36.000	0.000	0.000	A
41	33/9-1	2668	ND	2707.000	39.000	0.000	0.000	P	ND	2808.000	101.000	0.465	47.000	PAP	2923.000	115.000	0.000	0.000	A3
42	33/9-3	2615	ND	2644.000	29.000	0.000	0.000	P	ND	NP				P2+					
43	33/9-5	2774	ND	2826.000	52.000	0.000	0.000	C	ND	2890.000	64.000	0.000	0.000	PA	2998.000	108.000	0.000	0.000	A2
44	33/9-6	3140	ND	3194.000	54.000	0.000	0.000	C	ND	3263.000	69.000	0.000	0.000	PA	3318.000	55.000	0.000	0.000	R
45	33/9-8	2881	ND	2934.000	53.000	0.000	0.000	C	ND	3005.000	71.000	0.000	0.000	P	3055.000	50.000	0.000	0.000	A
46	33/9-10	3415	ND	3418.000	3.000	0.000	0.000	C	Faulted?	3456.000	38.000	0.000	0.000	PA	3500.000	44.000	0.000	0.000	R
47	33/9-11	3253	ND	3314.000	61.000	0.000	0.000	C	ND	3393.000	167.000	0.089	7.000	PR	3436.000	43.000	0.000	0.000	A
48	33/12-6	3283	ND	3397.000	114.000	0.000	0.000	C	ND	3745.000	146.000	0.233	34.000	AP4+	3721.000	157.000	9.000	0.057	AP
49	34/2-2	ND	3515	3599.000	84.000	0.000	0.000	C	ND	3745.000	146.000	0.233	34.000	C	3840.000	95.000	0.000	0.000	AP
50	34/4-3	4139	ND	4225.000	86.000	0.000	0.000	C	ND	4295.000	70.000	0.100	25.000	C	4345.000	50.000	0.000	0.000	C
51	34/4-5	ND	3319	3408.000	89.000	0.000	0.000	C	ND	3489.000	81.000	0.309	25.000	PA	3559.000	70.000	3.000	0.043	C
52	34/7-5	2622	ND	2694.000	72.000	0.000	0.000	A	ND	2784.000	90.000	0.000	0.000	PA	2893.000	109.000	0.000	0.000	A2
53	34/8-1	2970	ND	3035.000	65.000	0.000	0.000	A	3074	3199.000	164.000	0.323	53.000	C	3292.000	93.000	8.000	0.086	A
54	34/10-1	1944	ND	2021.000	77.000	0.000	0.000	PC	ND	2094.000	73.000	0.795	58.000	P	2267.000	173.000	0.000	0.000	A2
55	34/10-2	3127	ND	3171.000	44.000	0.000	0.000	C	ND	3247.000	76.000	0.026	2.000	C	3324.000	77.000	0.000	0.000	A1
56	34/10-5	2150	ND	2239.000	89.000	0.000	0.000			2387.000	148.000	0.568	84.000	PAP	2559.000	172.000	0.000	0.000	RA
57	34/10-7	Eroded	Eroded						Eroded	1935.000	128.000	0.383	49.000	P2	2050.000	115.000	13.000	0.113	AP
58	34/10-9	1960	ND	2082.000	122.000	0.000	0.000	C	ND	2210.000	128.000	0.383	49.000	P	2374.000	164.000	0.000	0.000	RA
59	34/10-17	3001	ND	3107.000	106.000	0.000	0.000	C	ND	3267.000	160.000	0.306	49.000	P4+	3422.000	155.000	10.000	0.065	RA
60	34/10-18	2604	ND	2683.000	79.000	0.000	0.000	C	ND	2816.000	133.000	0.203	27.000	PAP	2978.000	162.000	0.000	0.000	AR
61	34/10-21	3553	ND	3629.000	76.000	0.000	0.000	A	ND	3740.000	111.000	0.162	18.000	PAR	3906.000	166.000	0.000	0.000	A3
62	34/10-23	ND	4338	4412.000	74.000	0.000	0.000	?	ND	4538.000	126.000	0.341	43.000	C	4714.000	176.000	0.000	0.000	A3
63	35/3-2	3944	ND	3971.000	27.000	0.000	0.000	?	ND	4078.000	107.000	0.318							

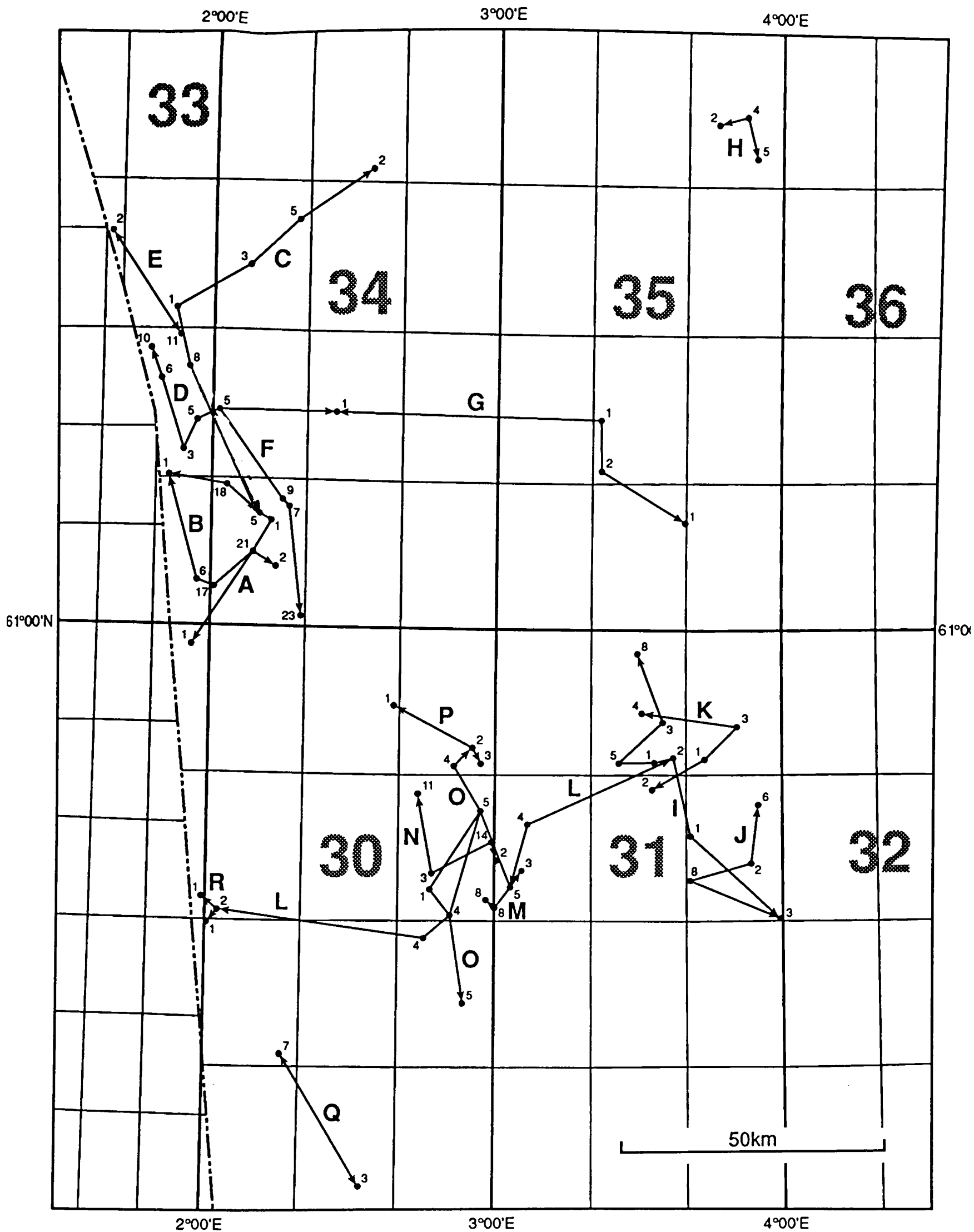


Figure 10.7 Study area showing location of study wells and lines of correlation panels (figs. 10.8-10.25)

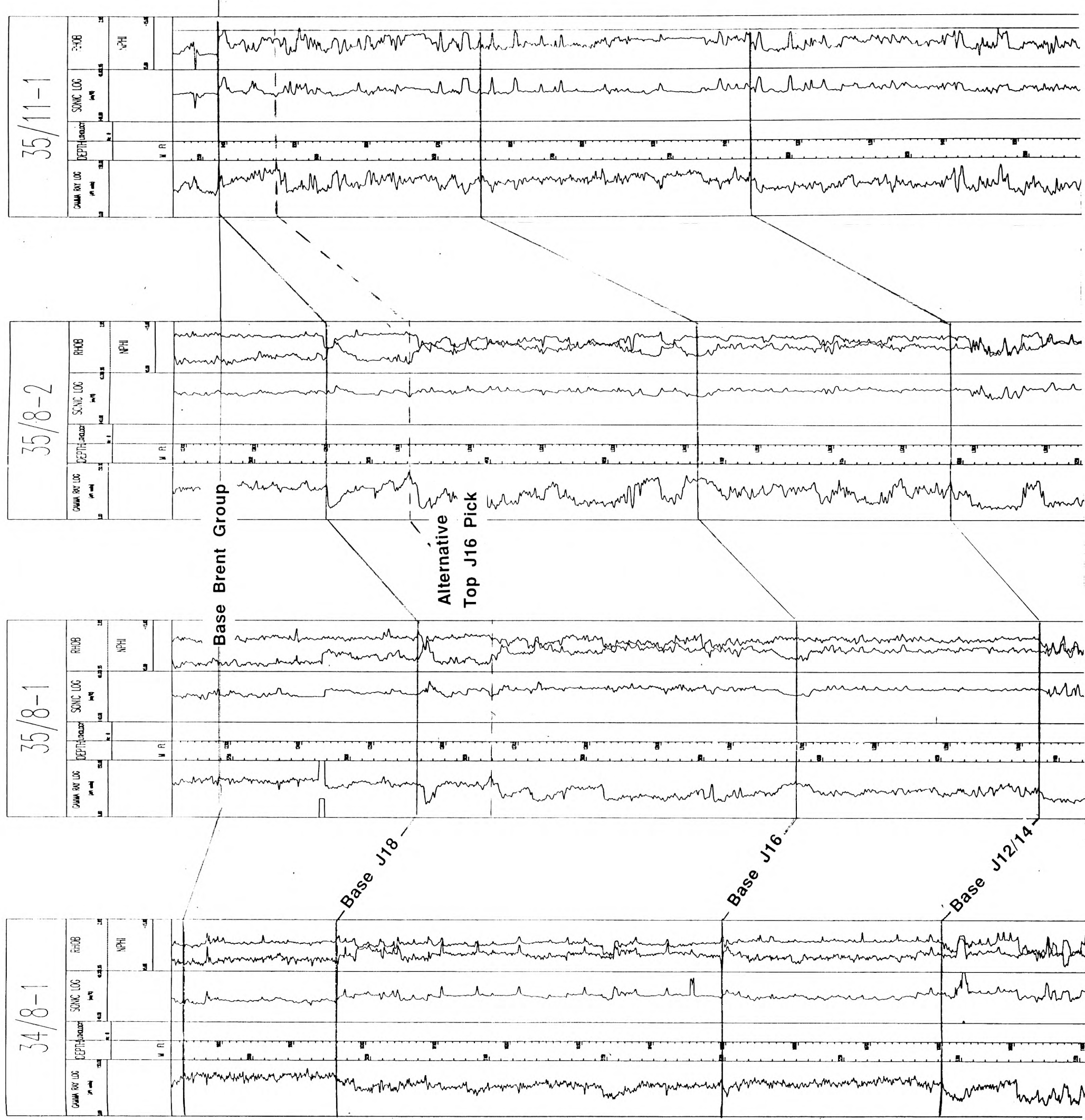
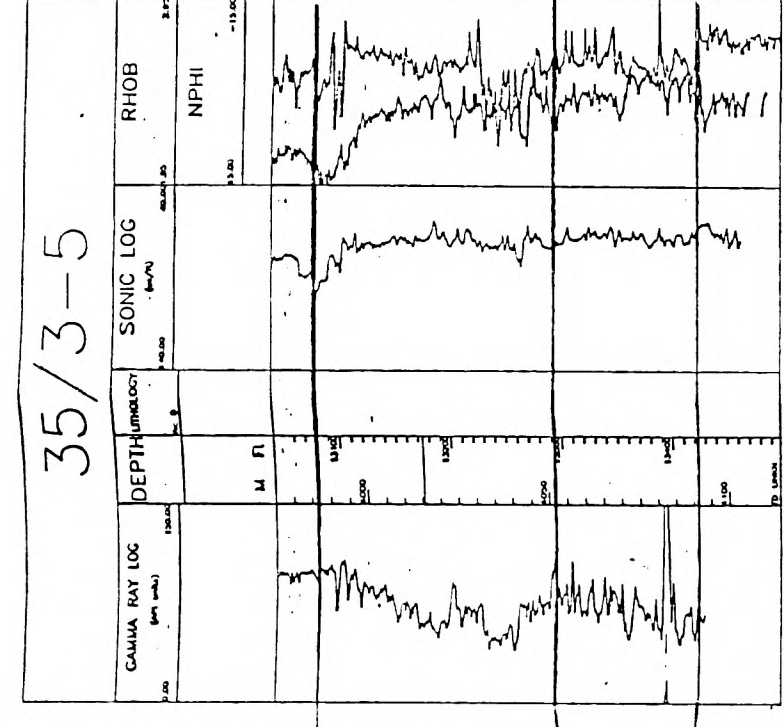
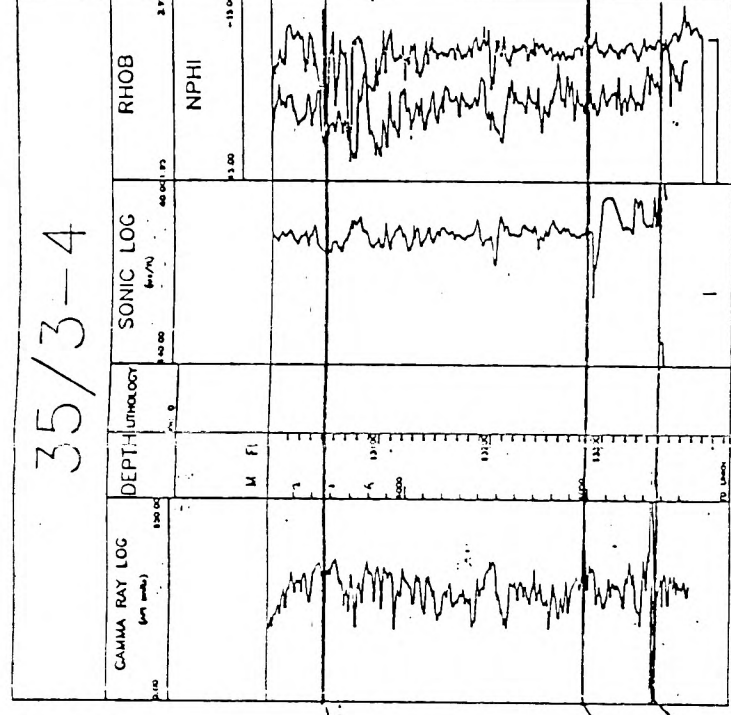
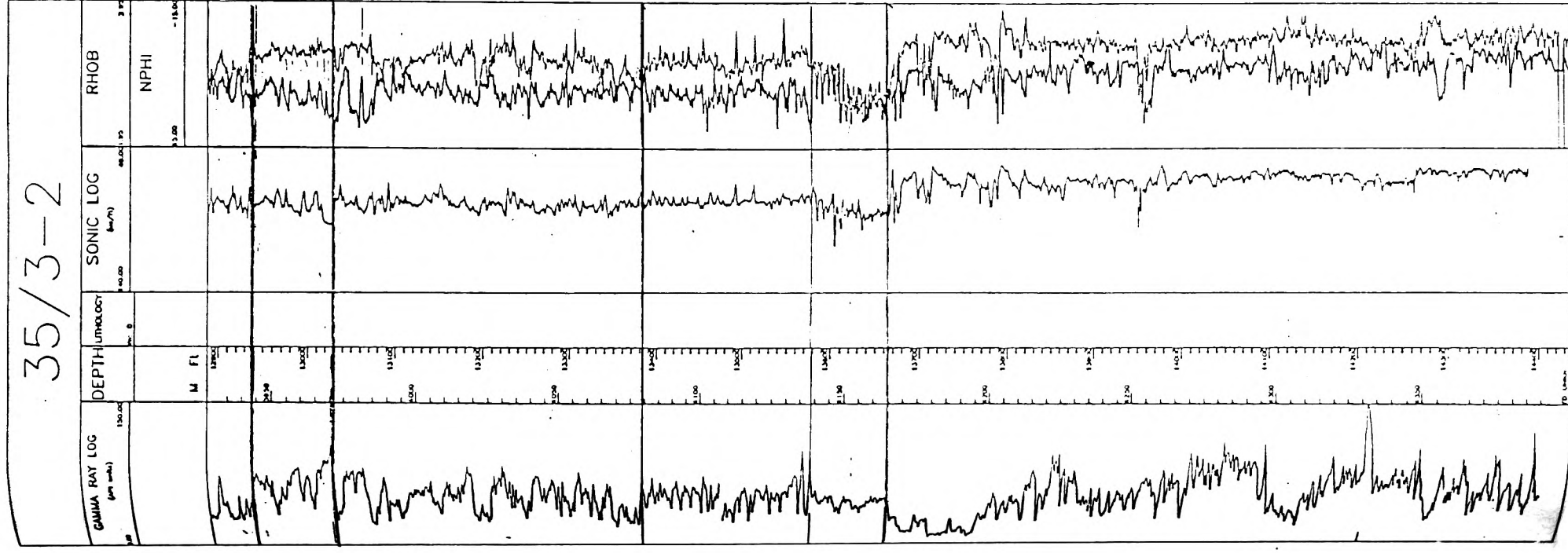


Figure 10.14 Correlation Panel "G" (see figure 10.7).



Base Brent Group

Base J18

Base J16

Base J12/14
Top Crystalline Basement

Figure 10.15 Correlation Panel "H" (see figure 10.7). The Lower Jurassic laps out onto basement in this area.

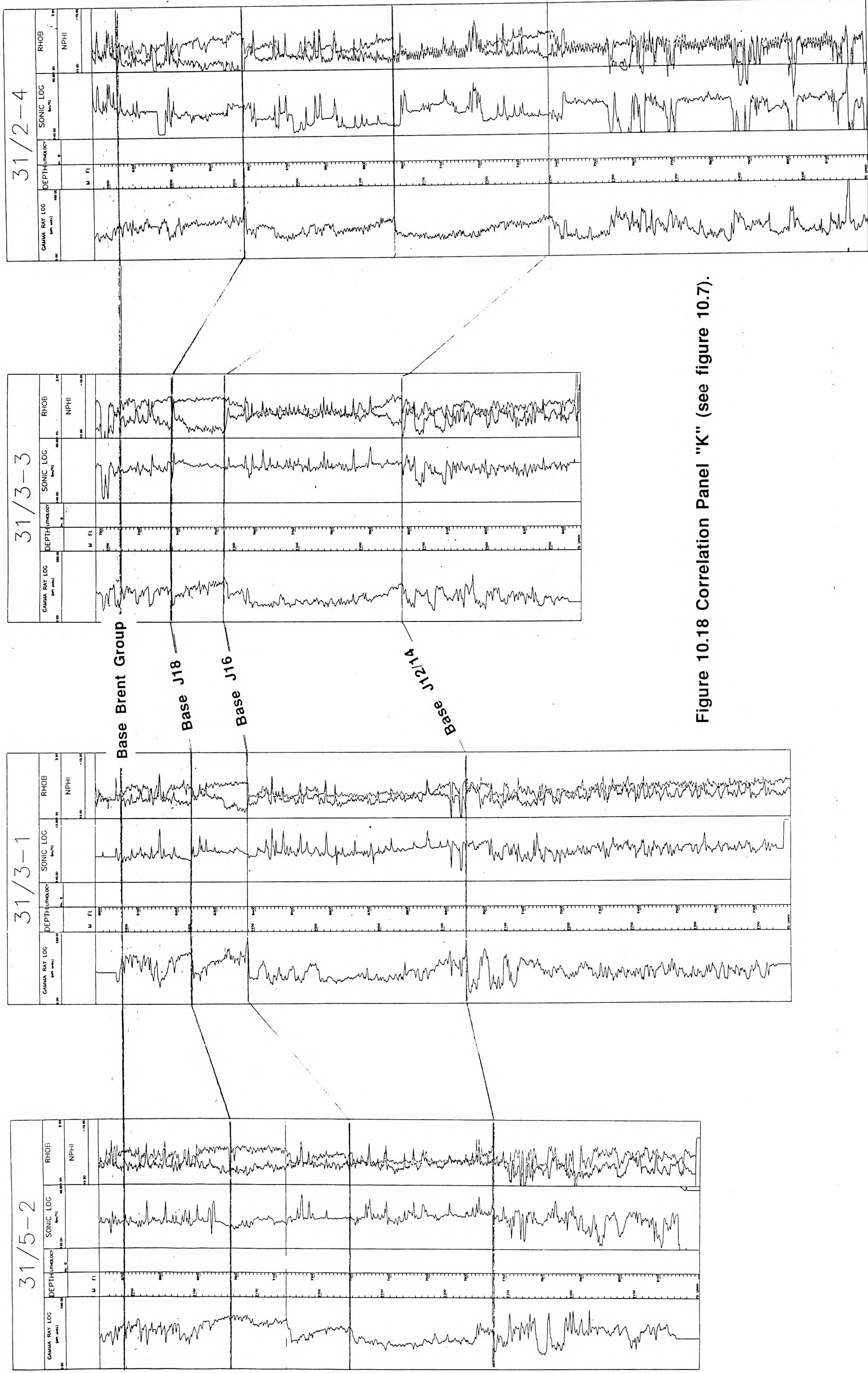


Figure 10.18 Correlation Panel "K" (see figure 10.7).

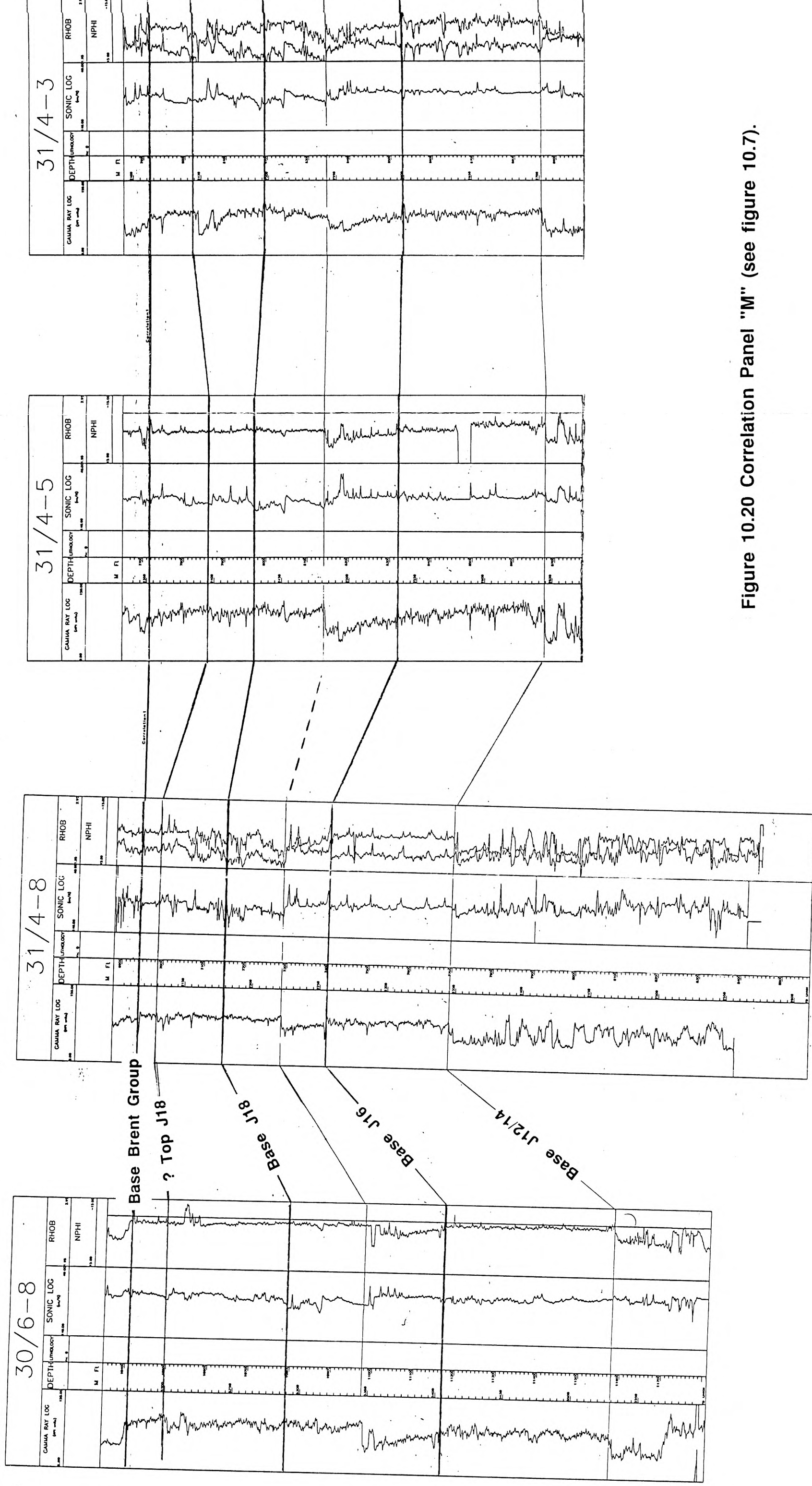


Figure 10.20 Correlation Panel "M" (see figure 10.7).

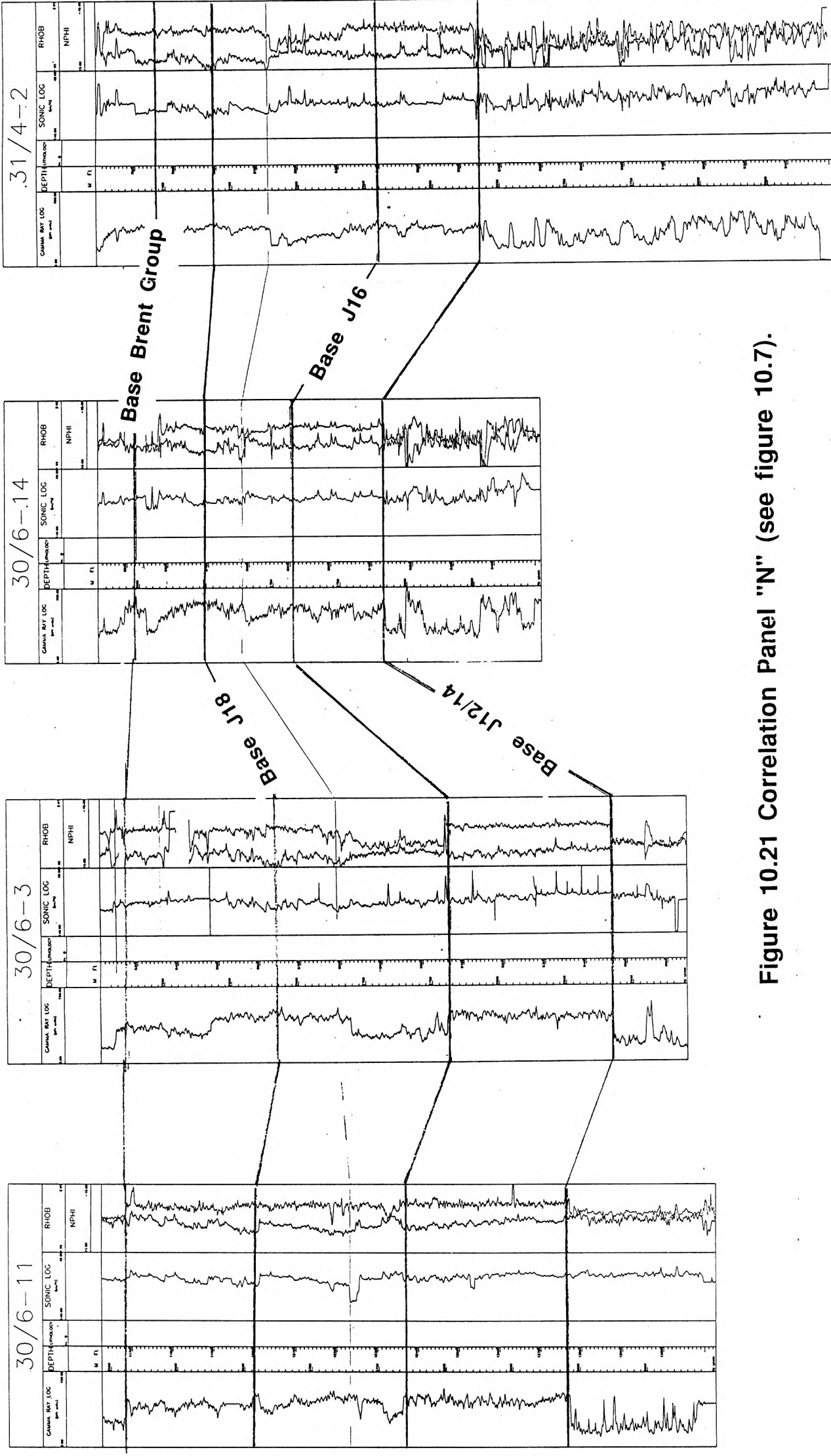
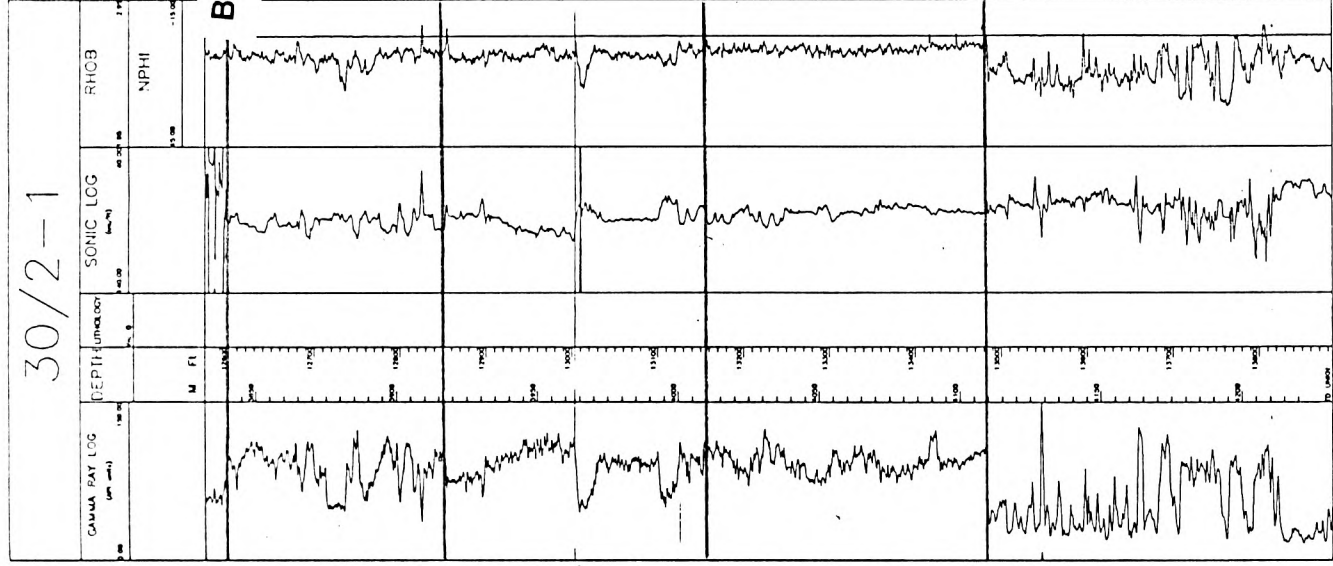


Figure 10.21 Correlation Panel "N" (see figure 10.7).



Base Brent Group

Base J18

Base J16

Base J12/14

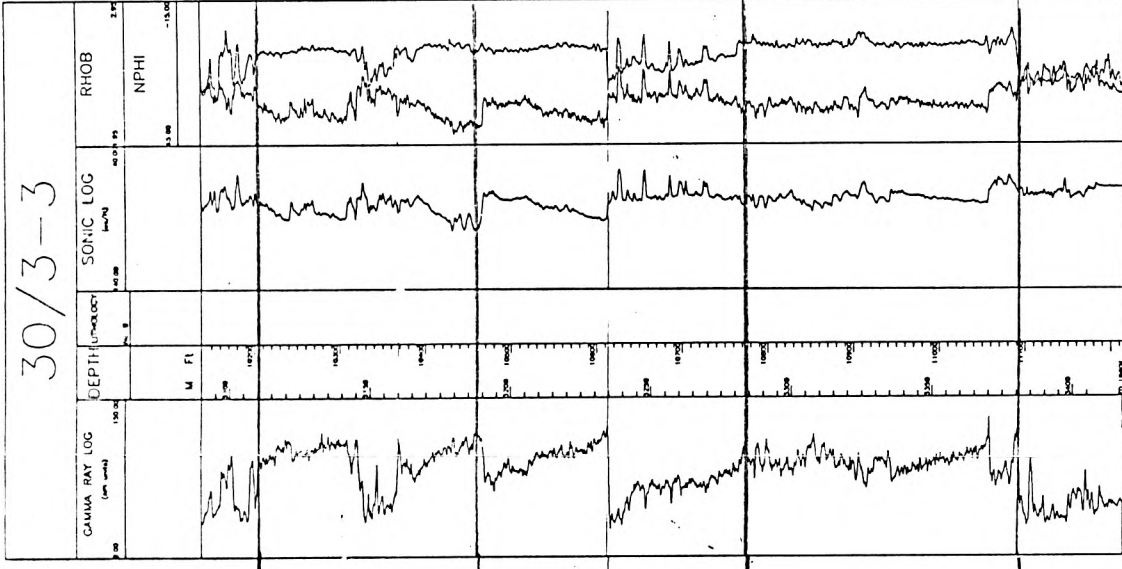
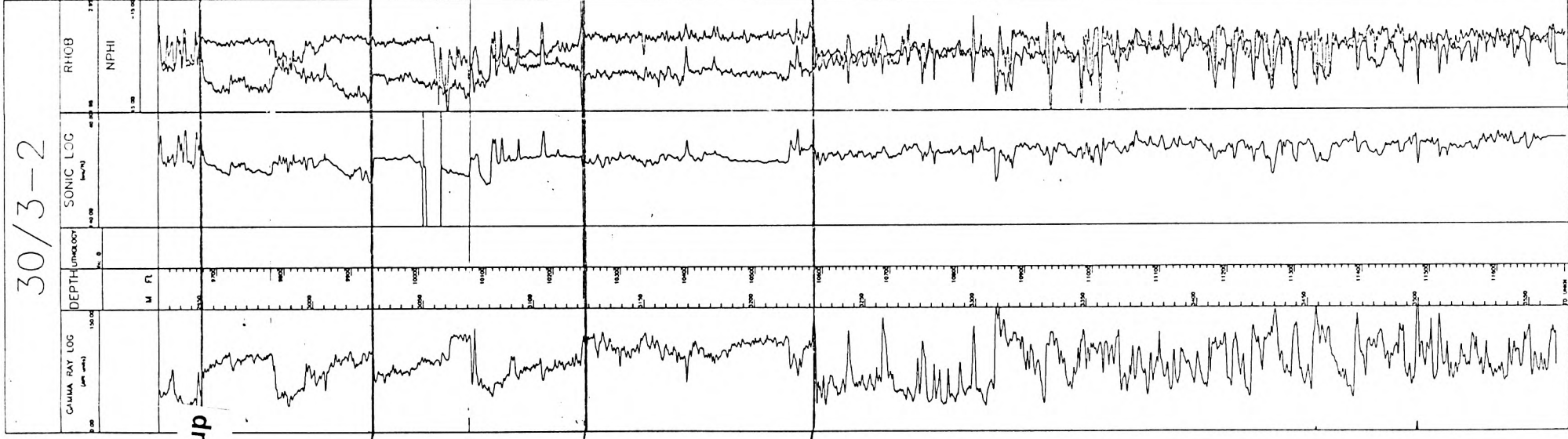


Figure 10.23 Correlation Panel "P"
(see figure 10.7).

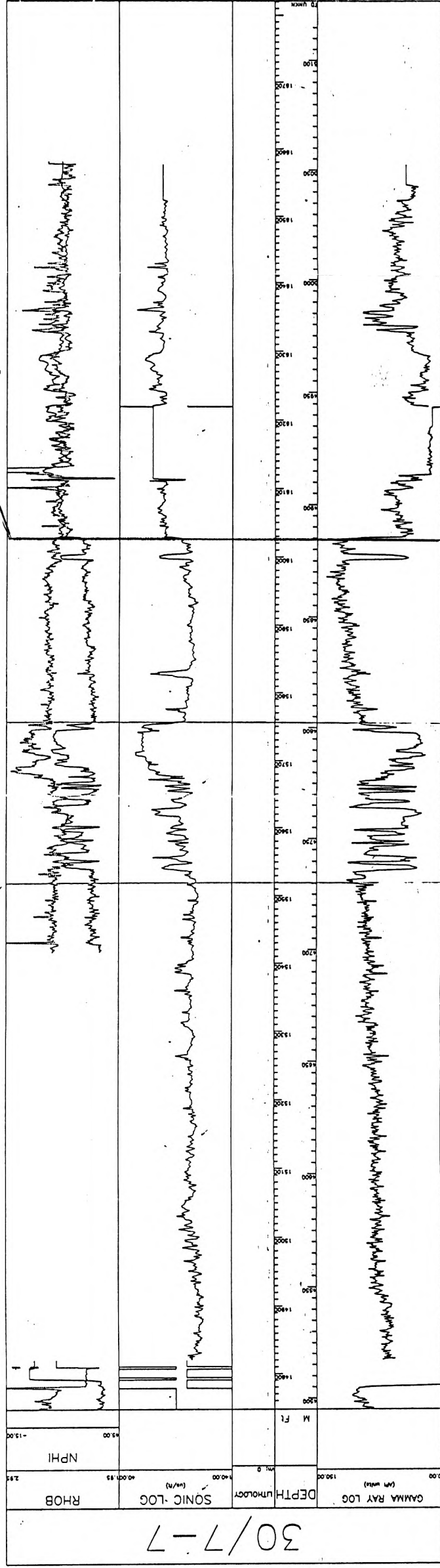
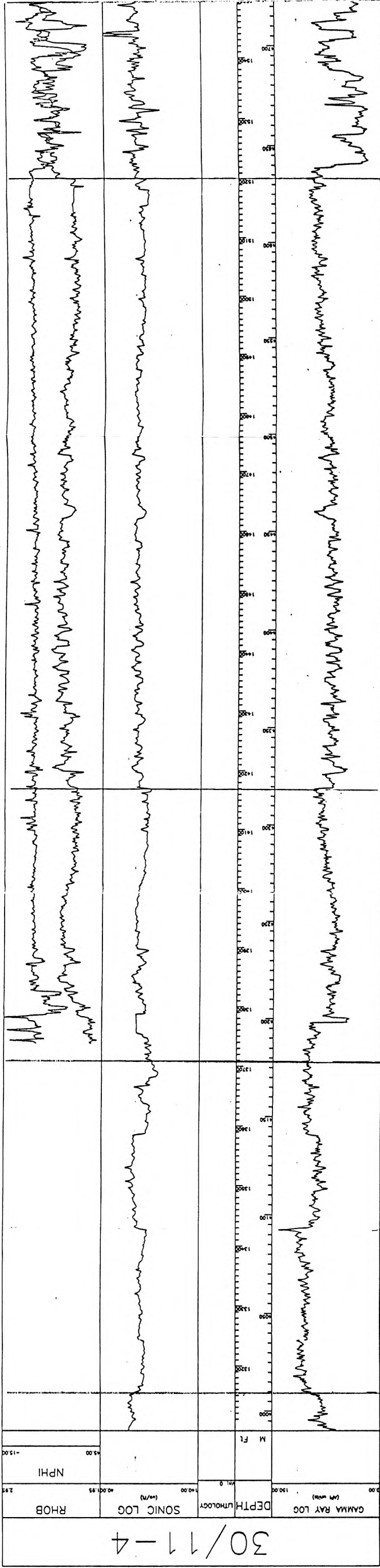


Figure 10.24 Correlation Panel "Q" (see figure 10.7).

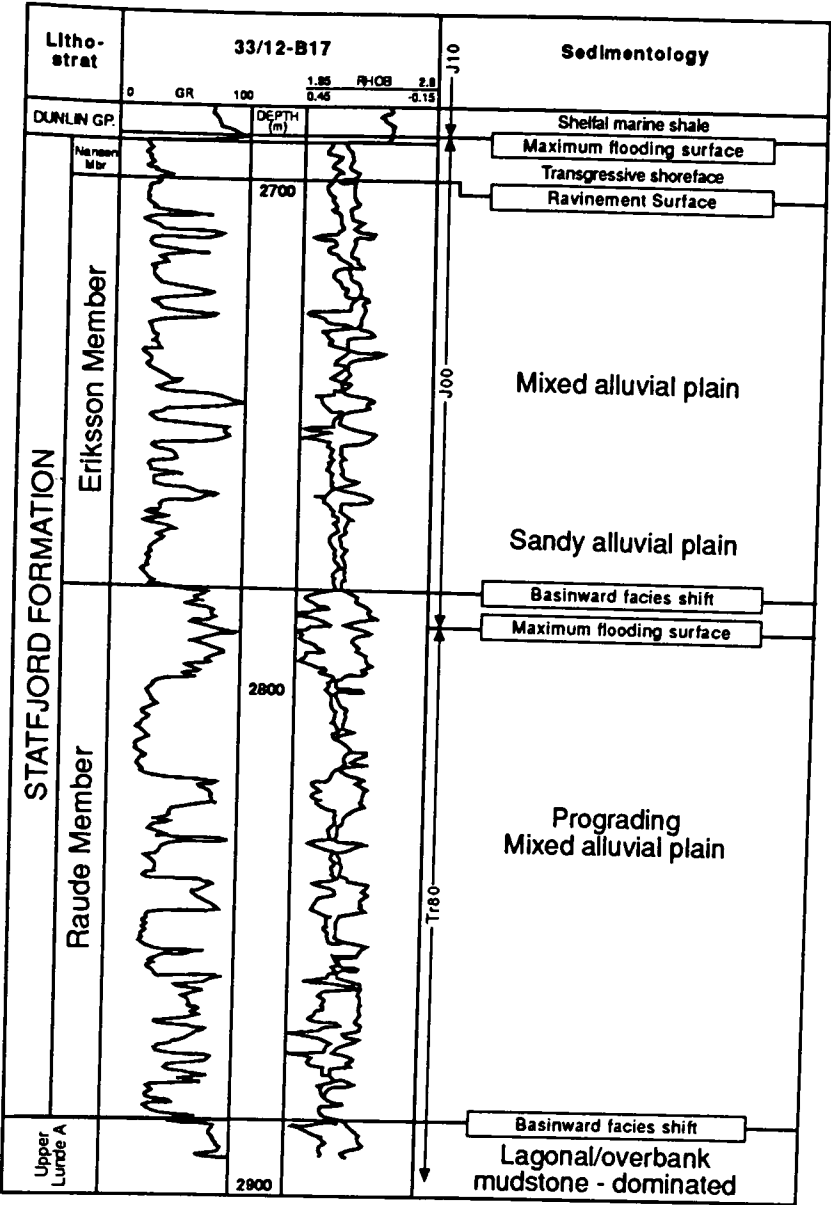
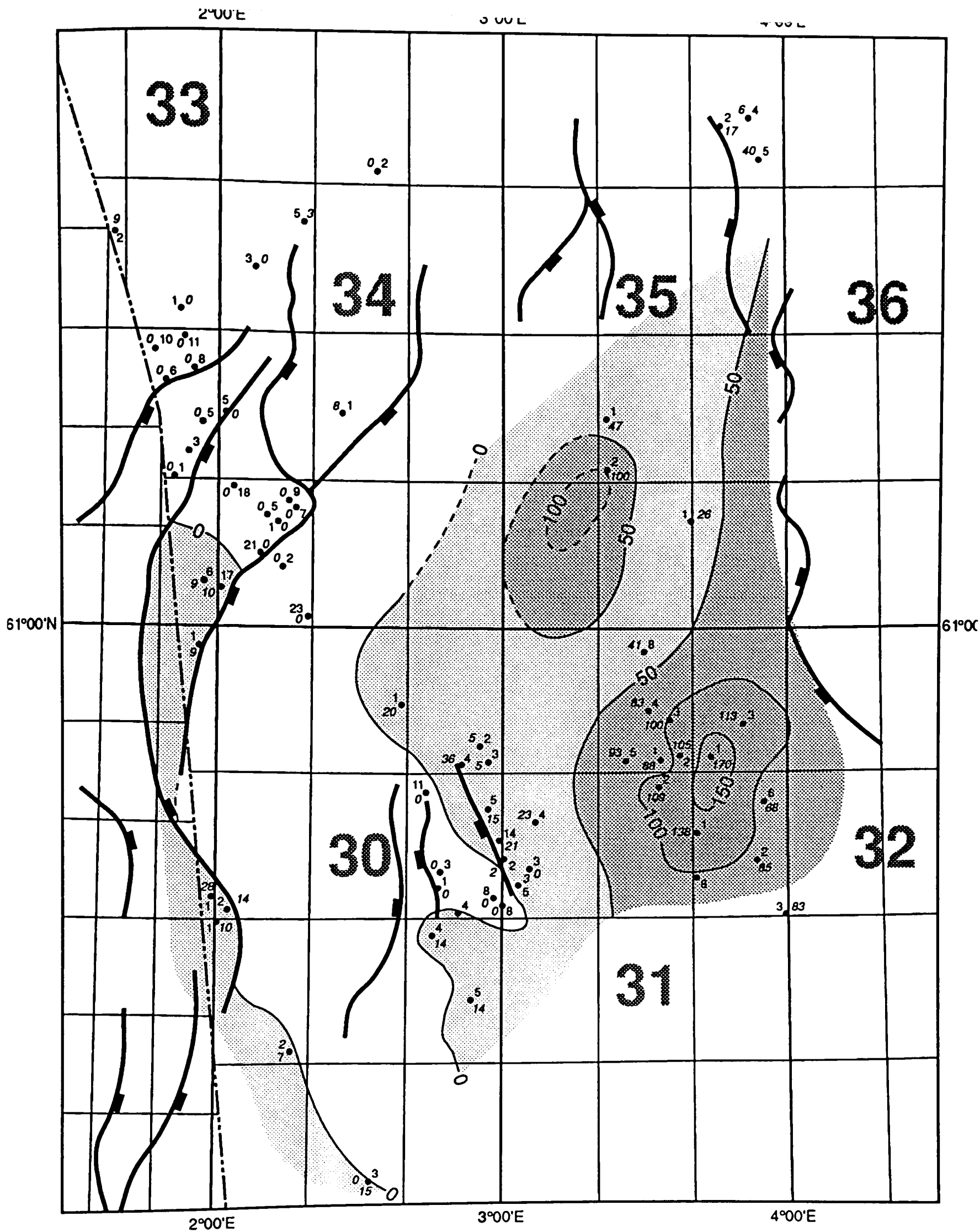


Figure 10.26 Typical stratigraphy of the Tr80/J00 cycle (well 33/12-B17, Statfjord Field). From Parkinson & Hines, in press.



J12/14 SAND ISOCHORE

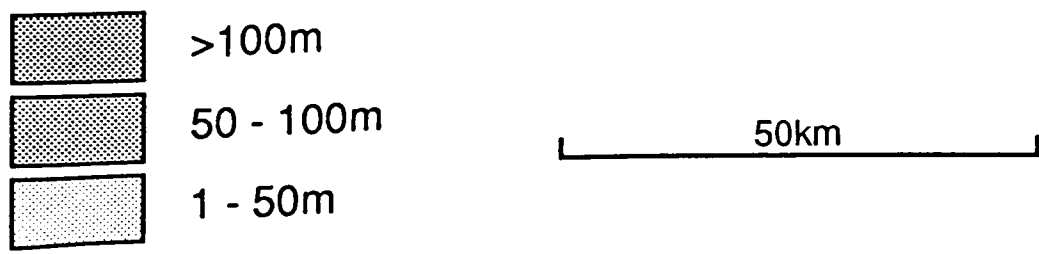
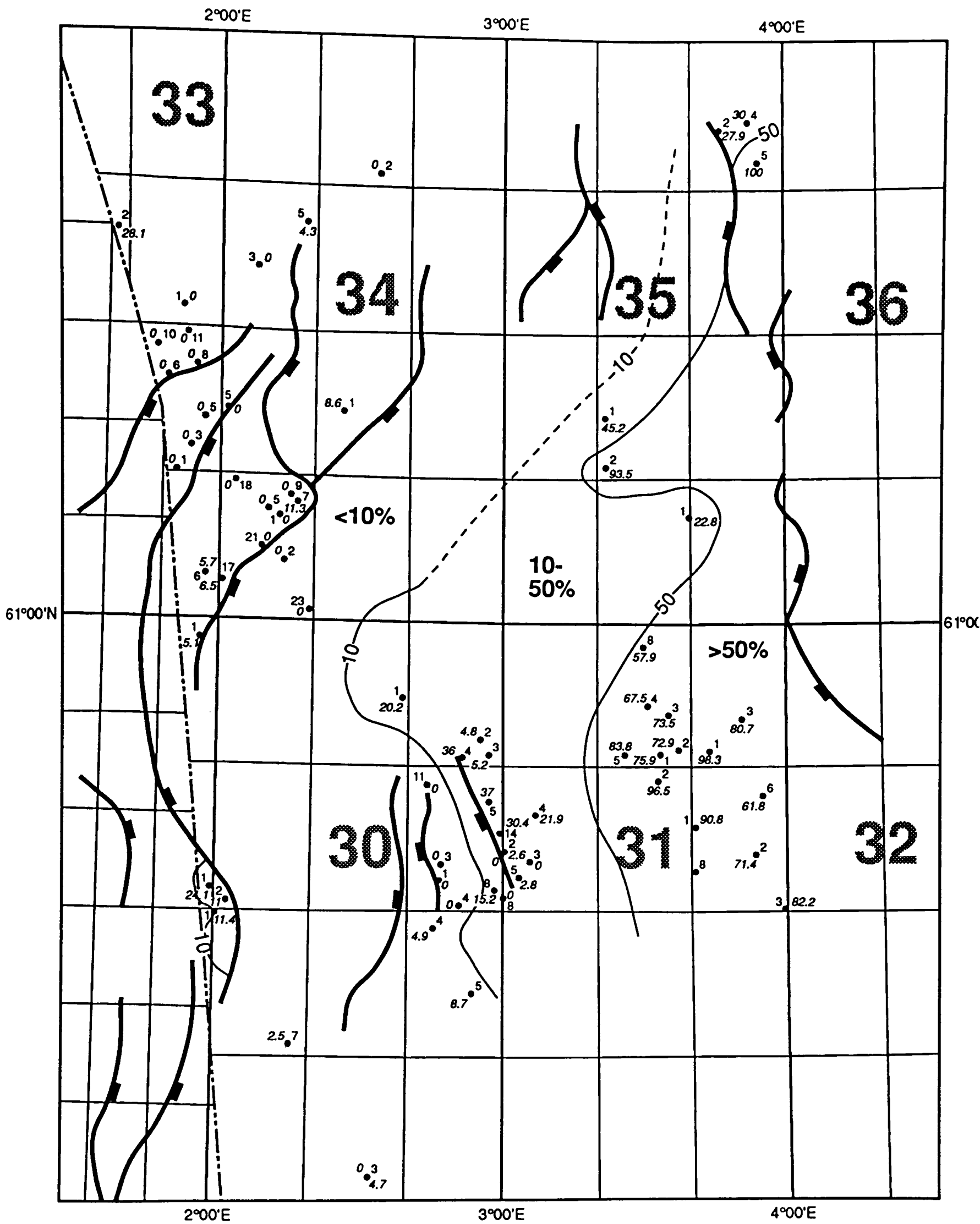
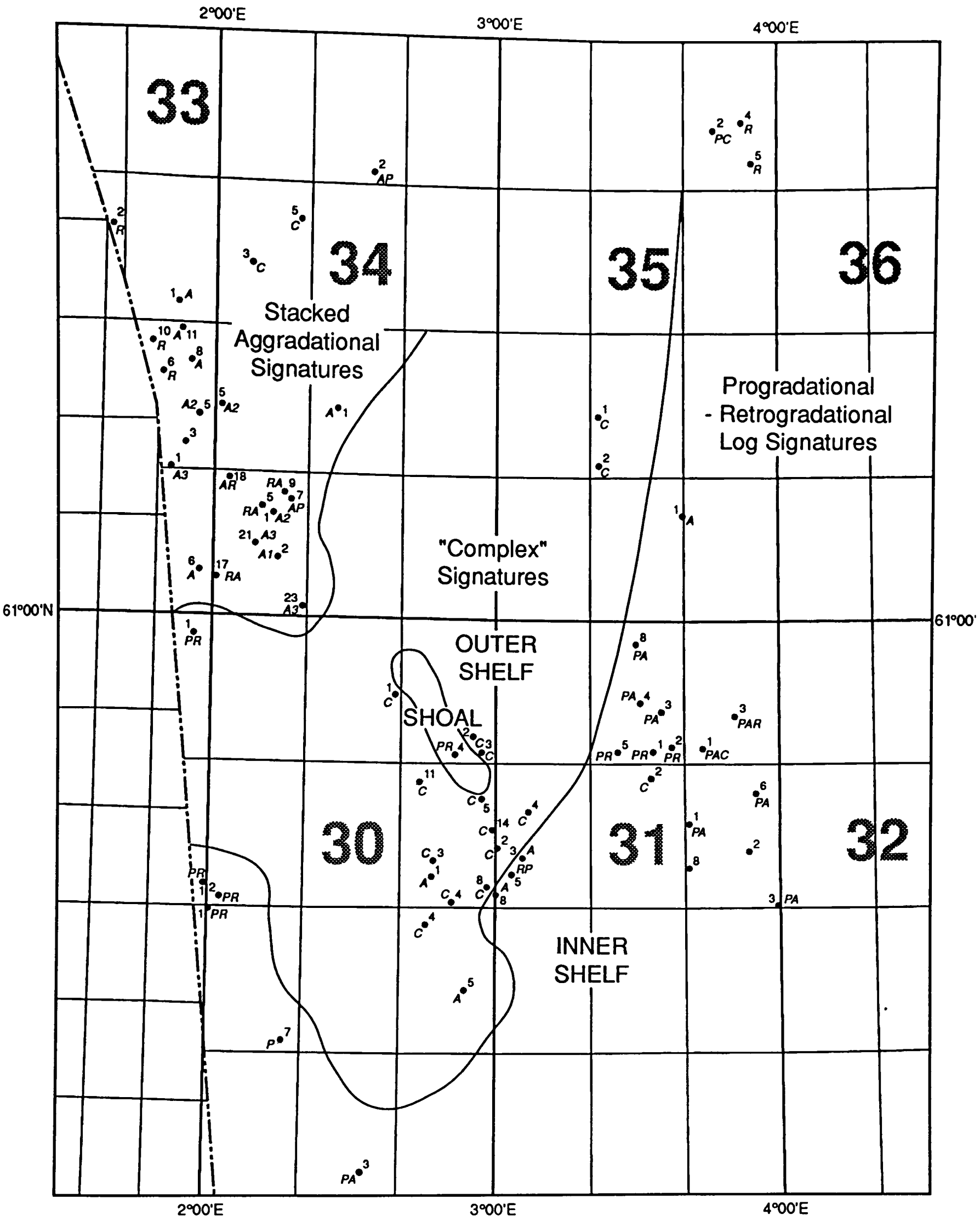


Figure 10.28



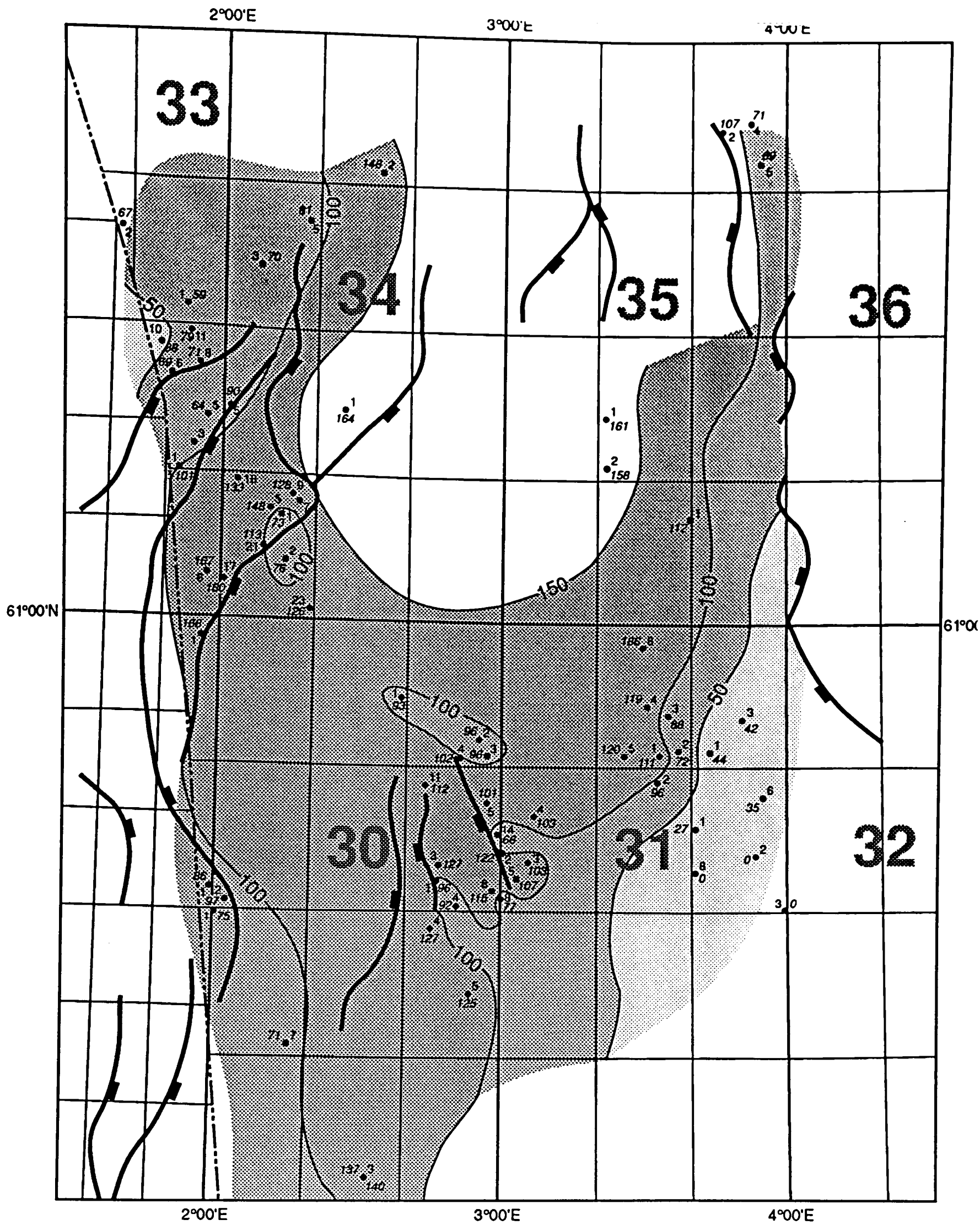
J12/14 SAND/SHALE PERCENTAGES

50km

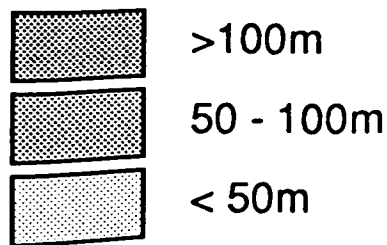


J12/14 FACIES

Figure 10.30

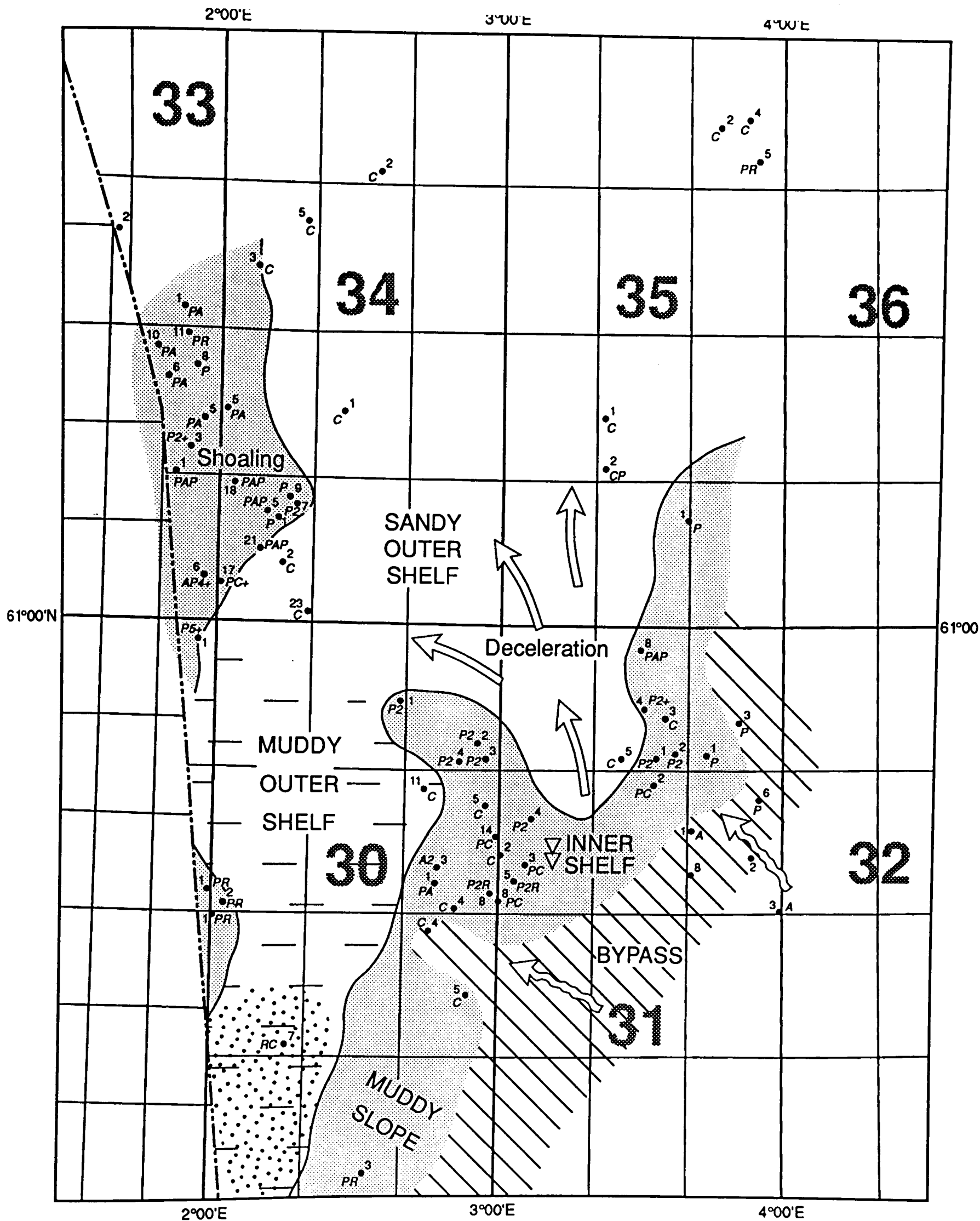


J16 ISOCHORE



50km

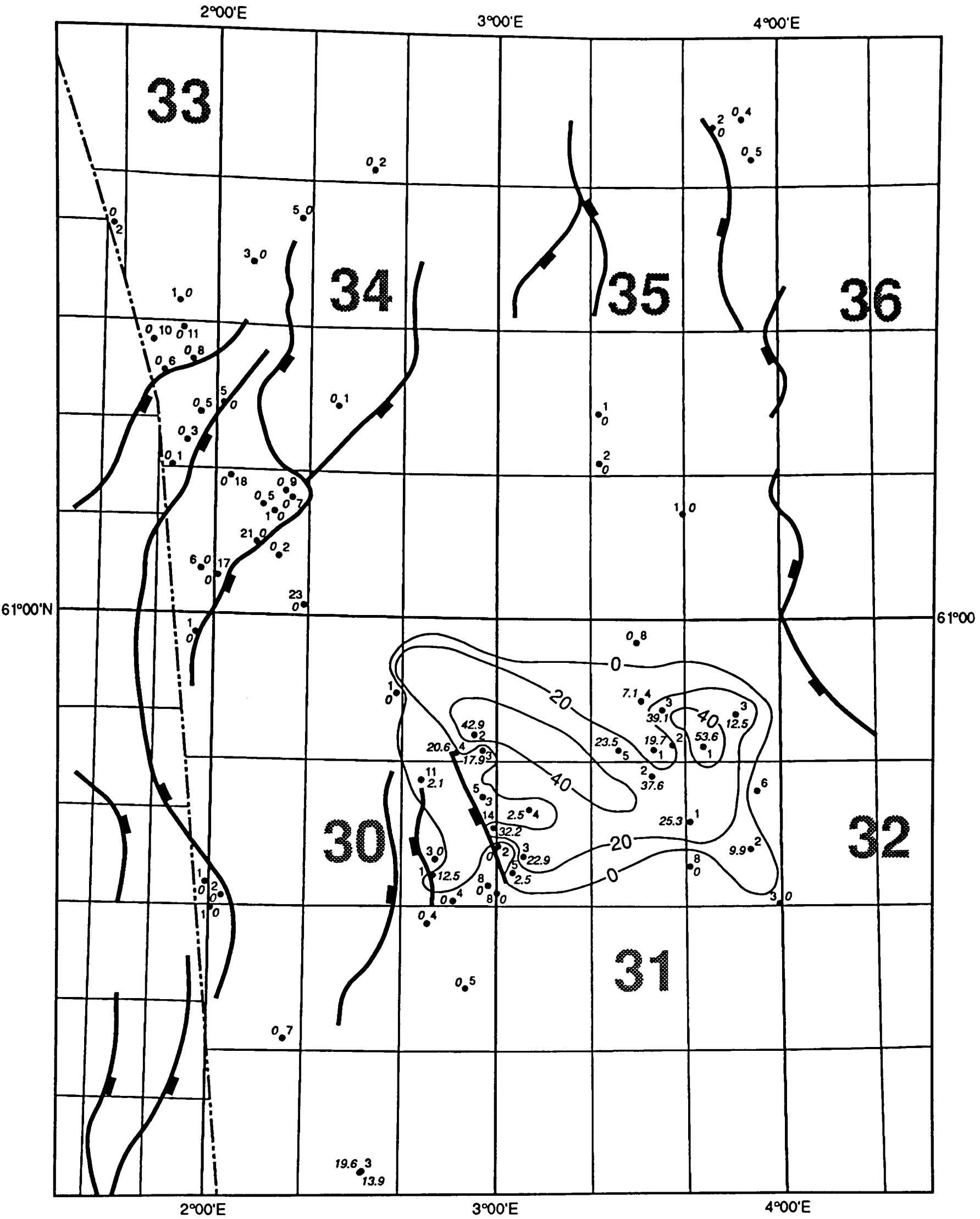
Figure 10.31



J16 FACIES

50km

Figure 10.34



J18 SAND/SHALE PERCENTAGES

50km

Figure 10.36

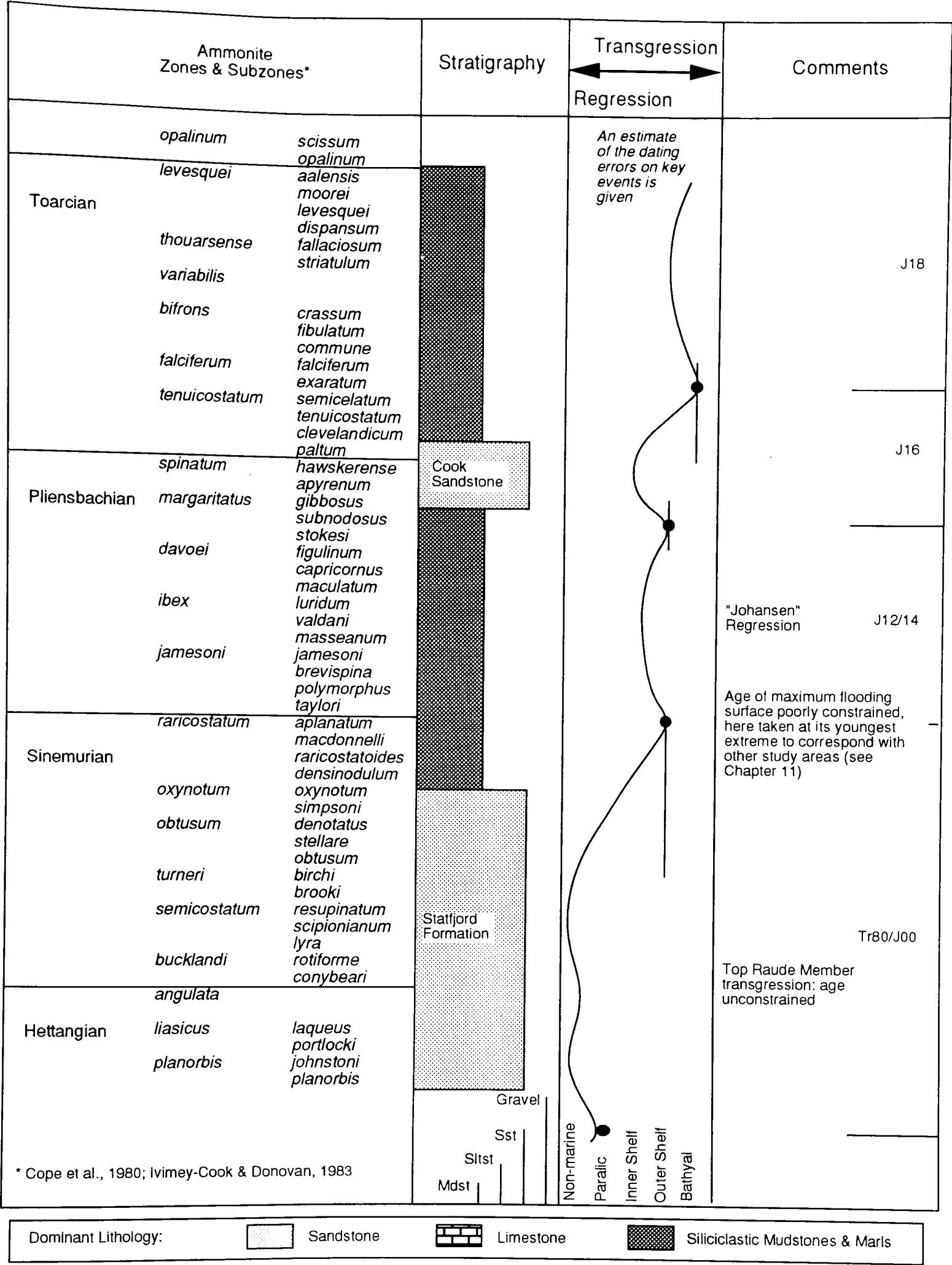


Figure 10.37 Summary of stratigraphic events in the North Viking Graben (Norwegian North Sea)

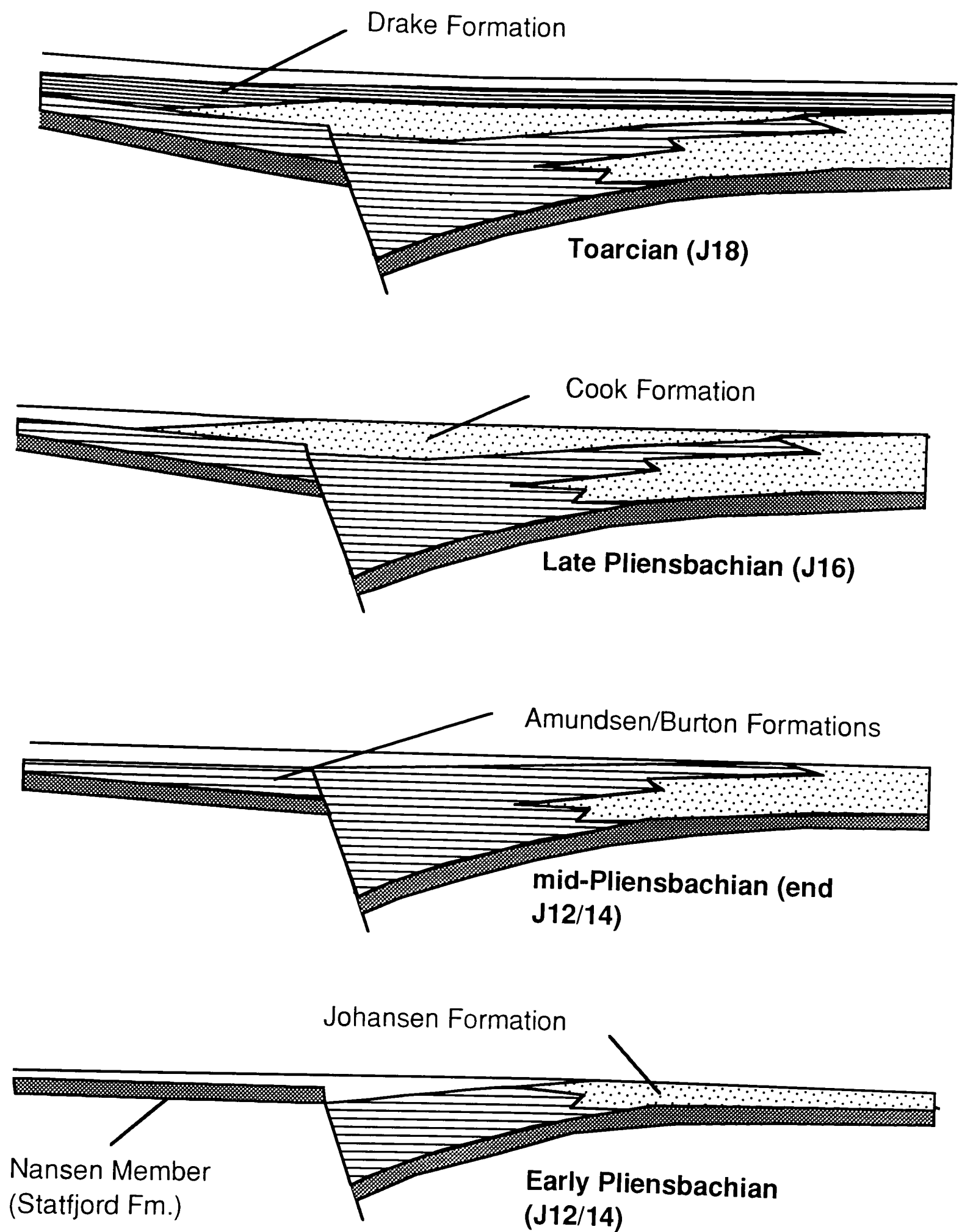


Figure 10.38 Cartoon Stratigraphic Development of the Dunlin Group in the North Viking Graben

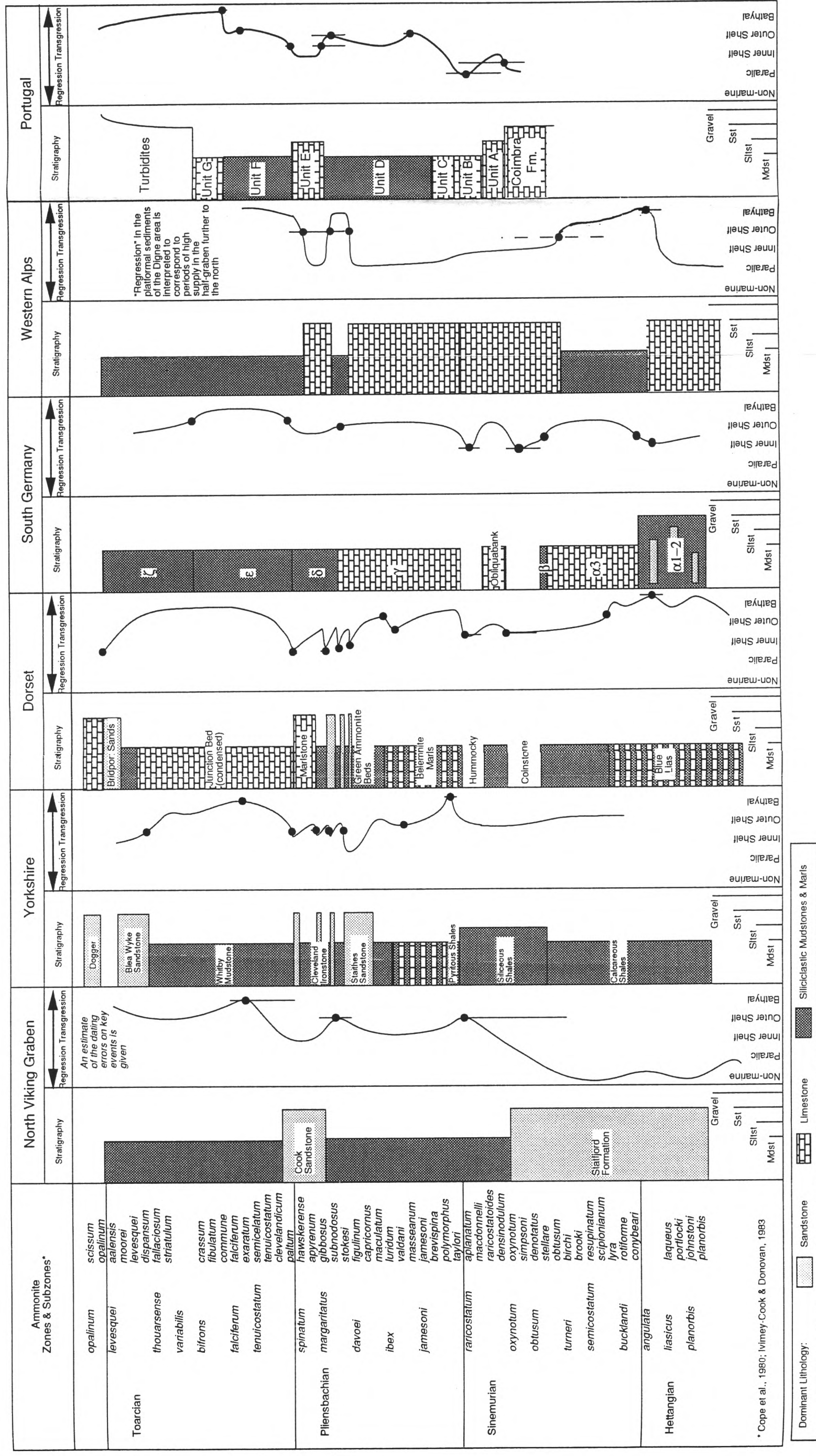
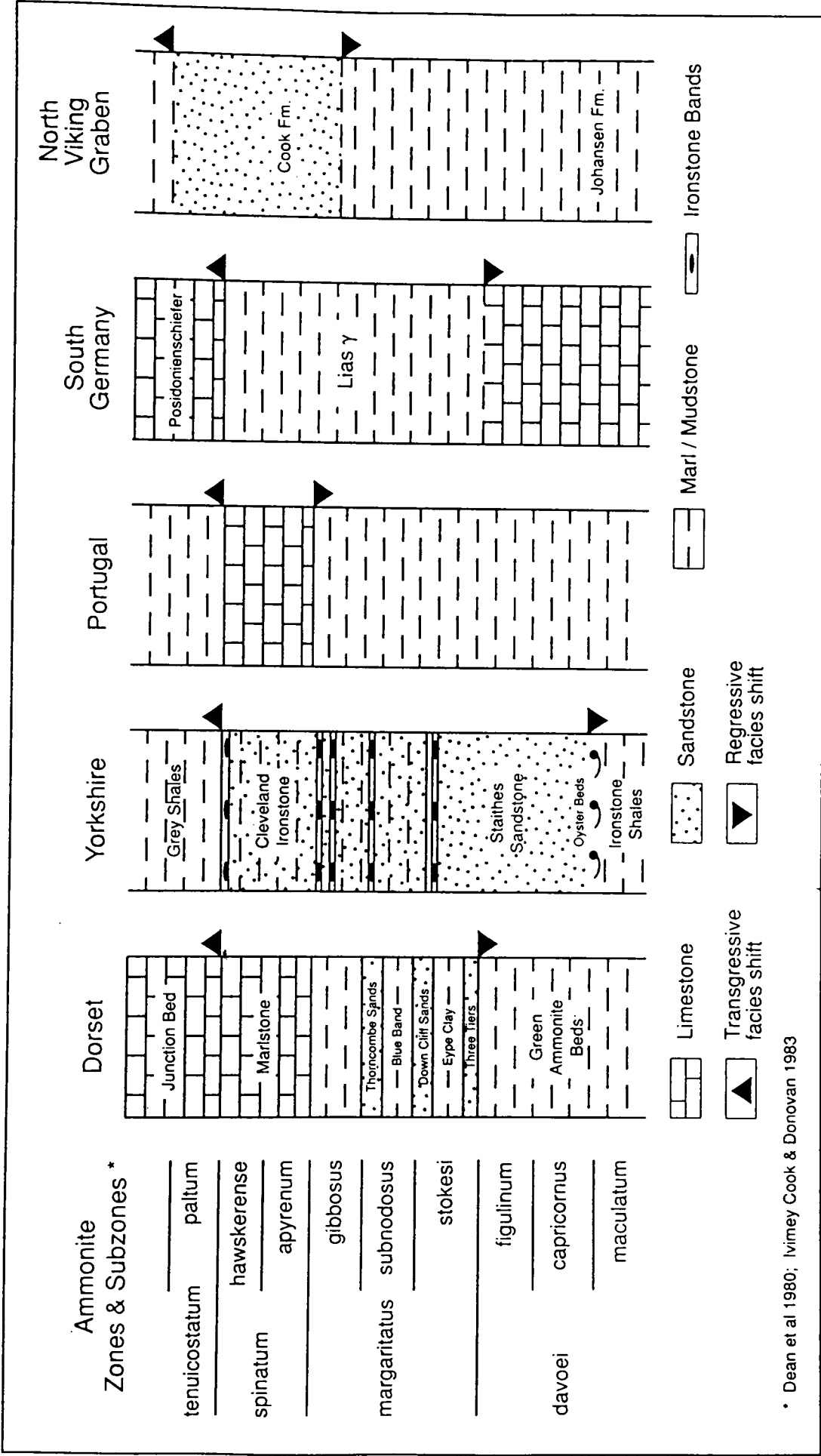


Figure 11.1 Comparison of Study Areas



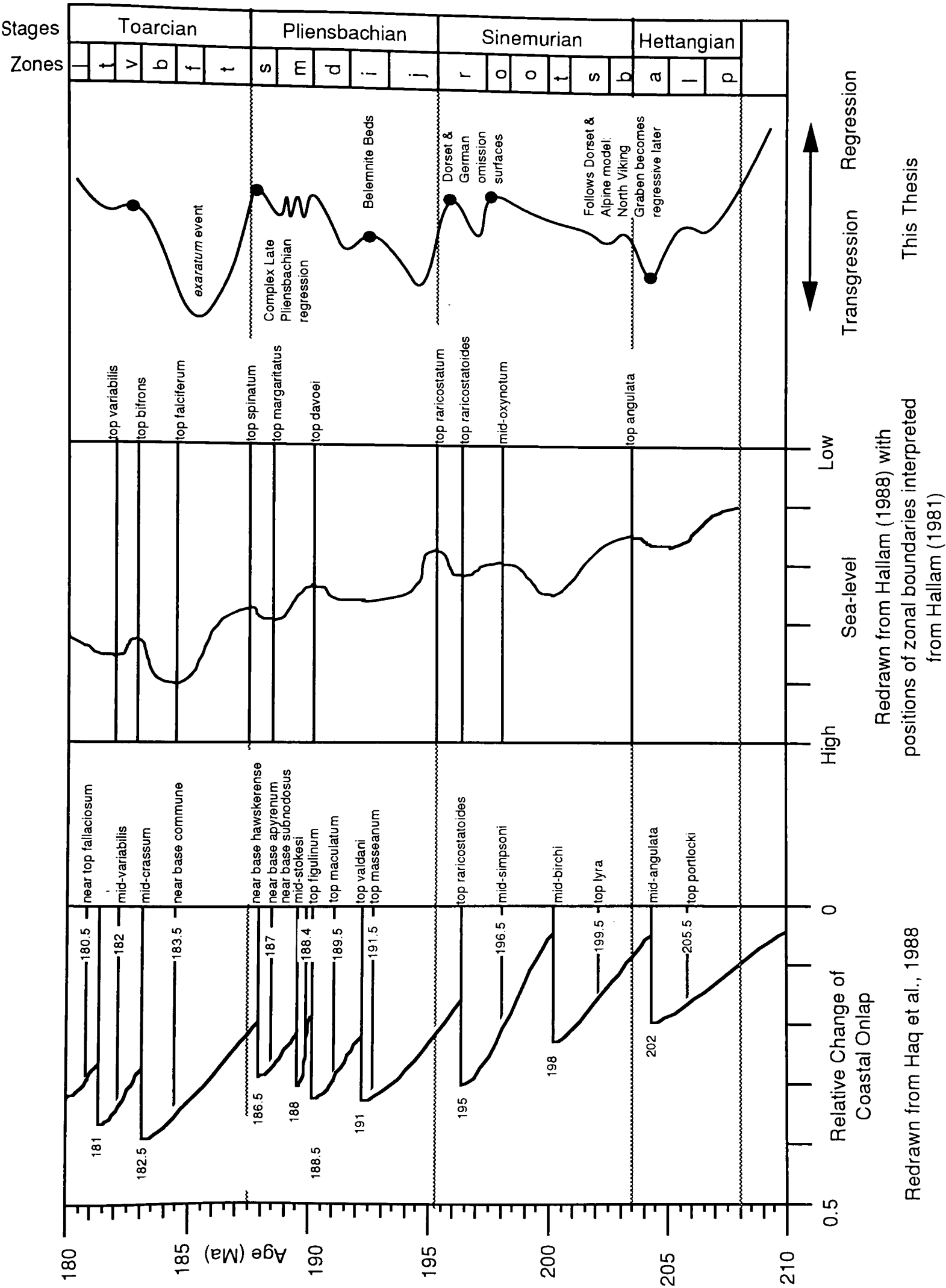


Figure 11.3 A representation of the Early Jurassic "stratigraphic signature" interpreted from this work compared with the coastal onlap curve of Haq et al. (1988) and the sea-level curve of Hallam (1988)

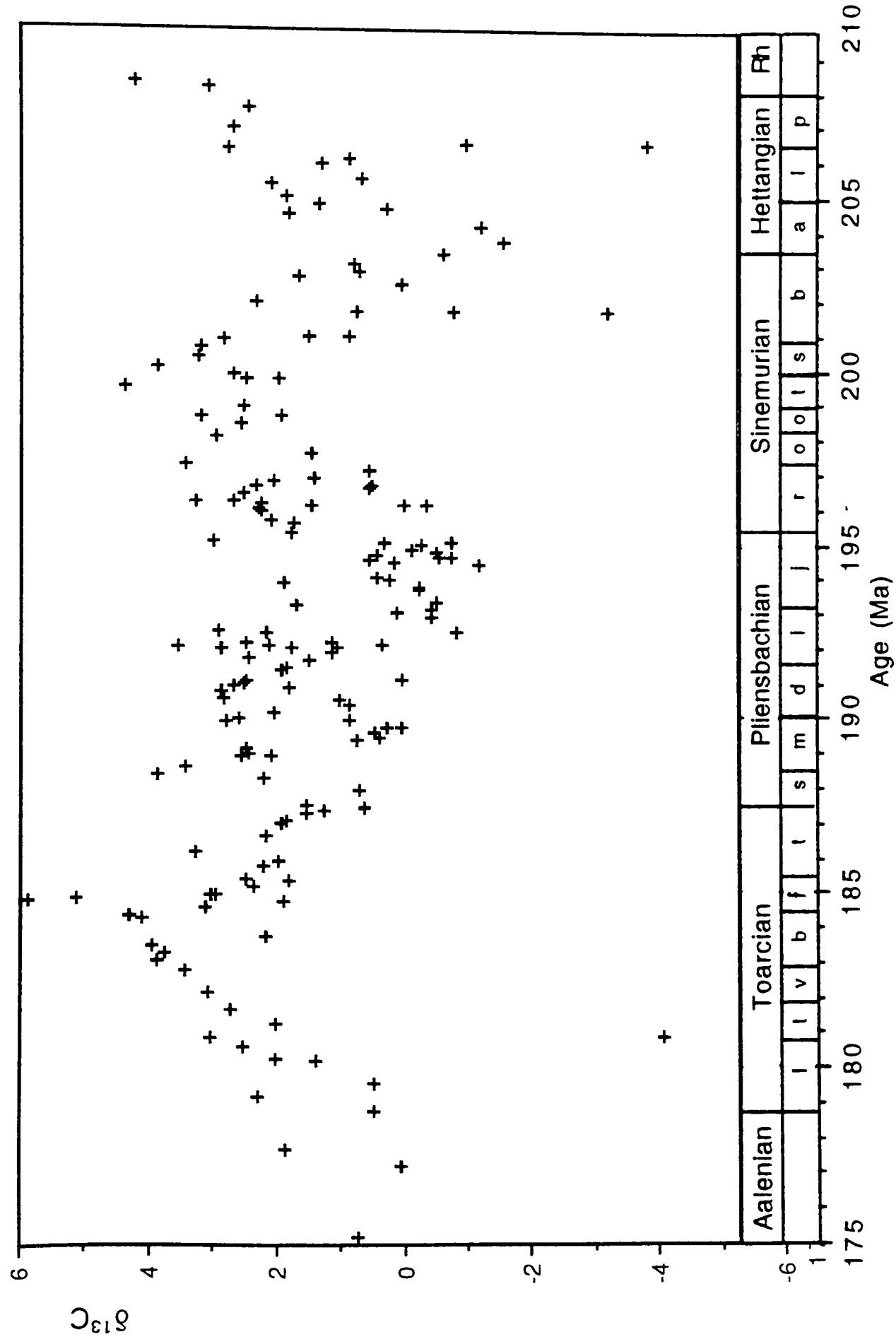


Figure 12.1 Carbon-isotope data for the UK Lower Jurassic (Jones,1992)

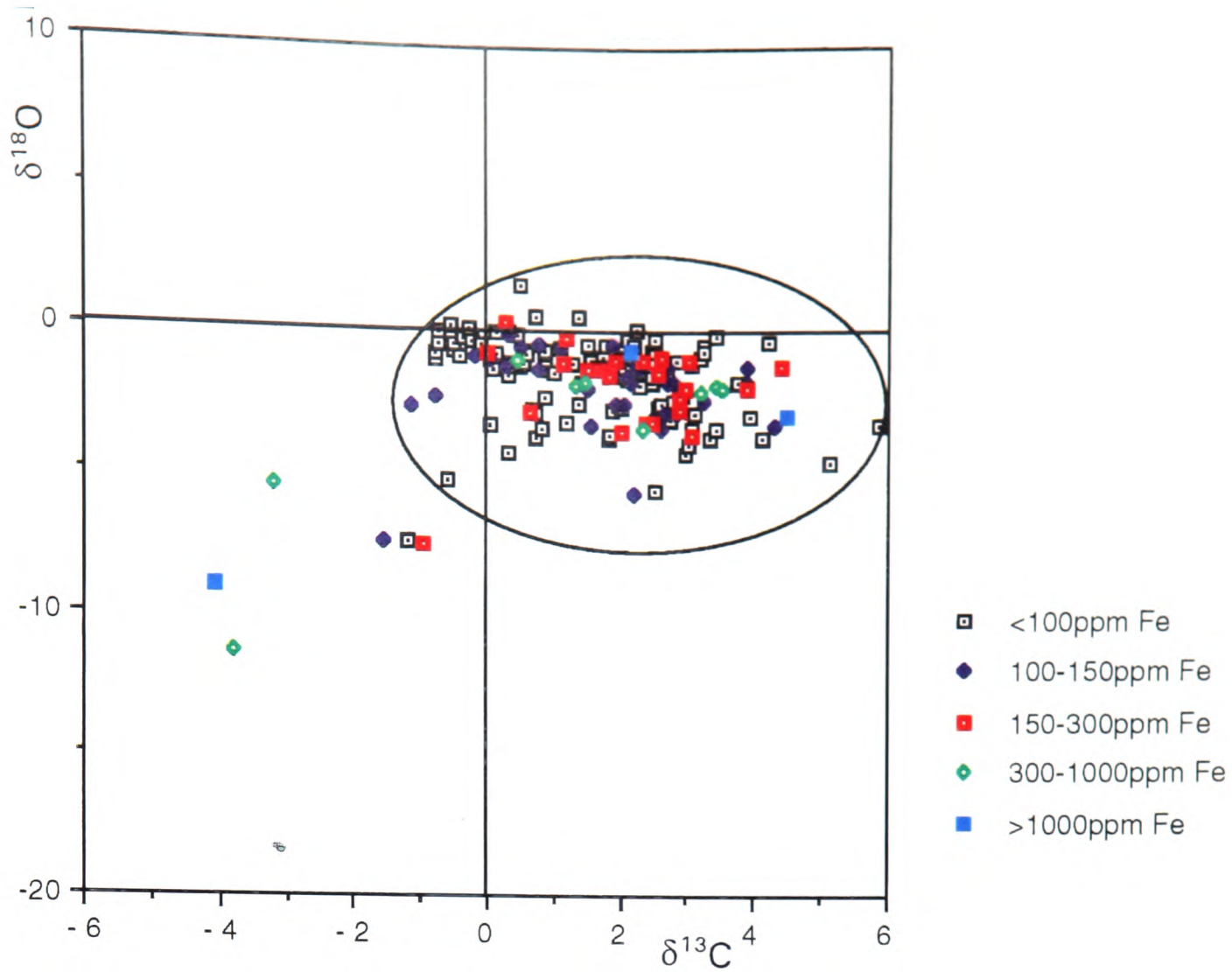


Figure 12.2a $\delta^{13}\text{C}$ v. $\delta^{18}\text{O}$ Data of Jones (1992)

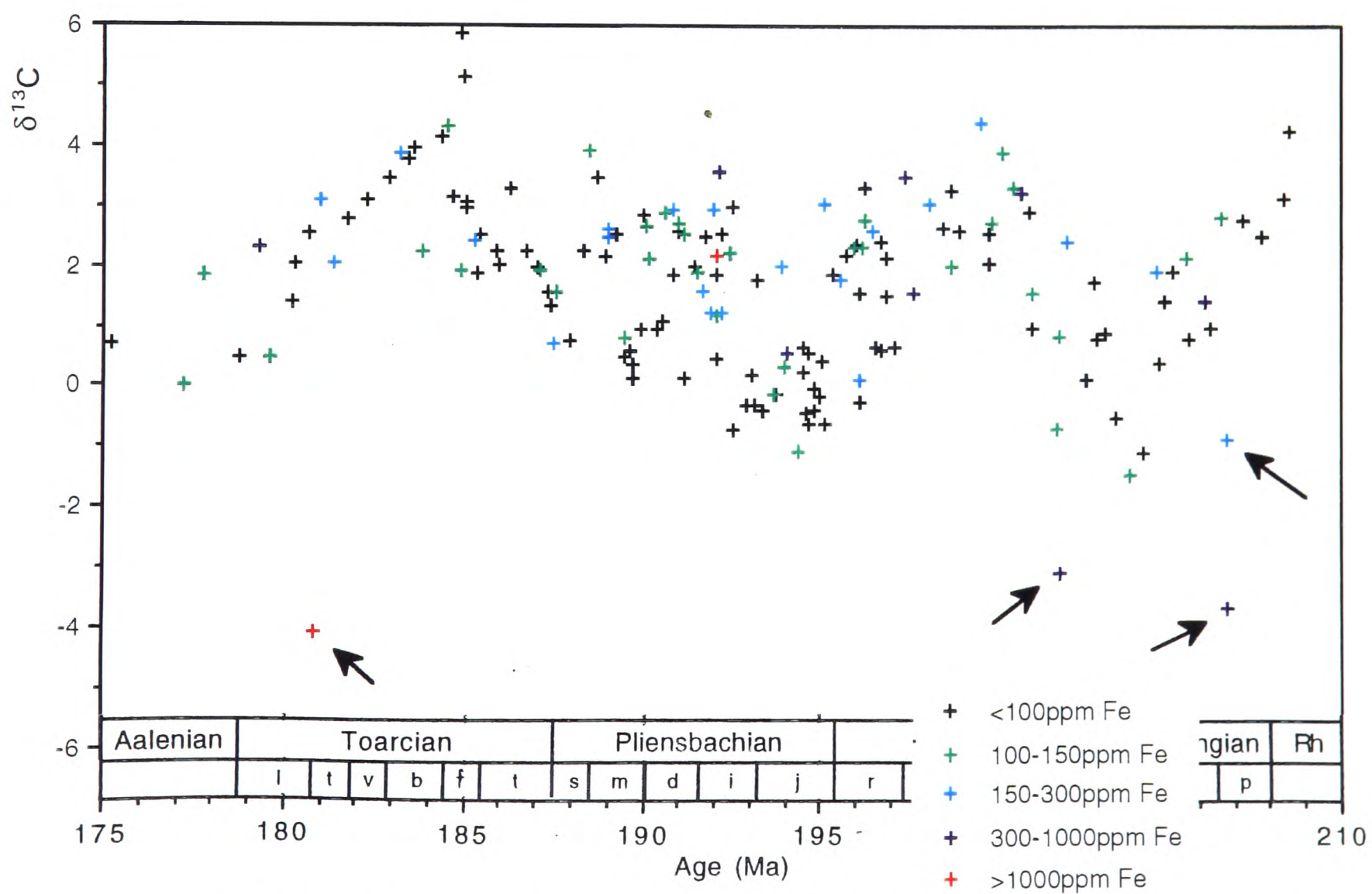


Figure 12.2b Jones (1992) data showing iron content

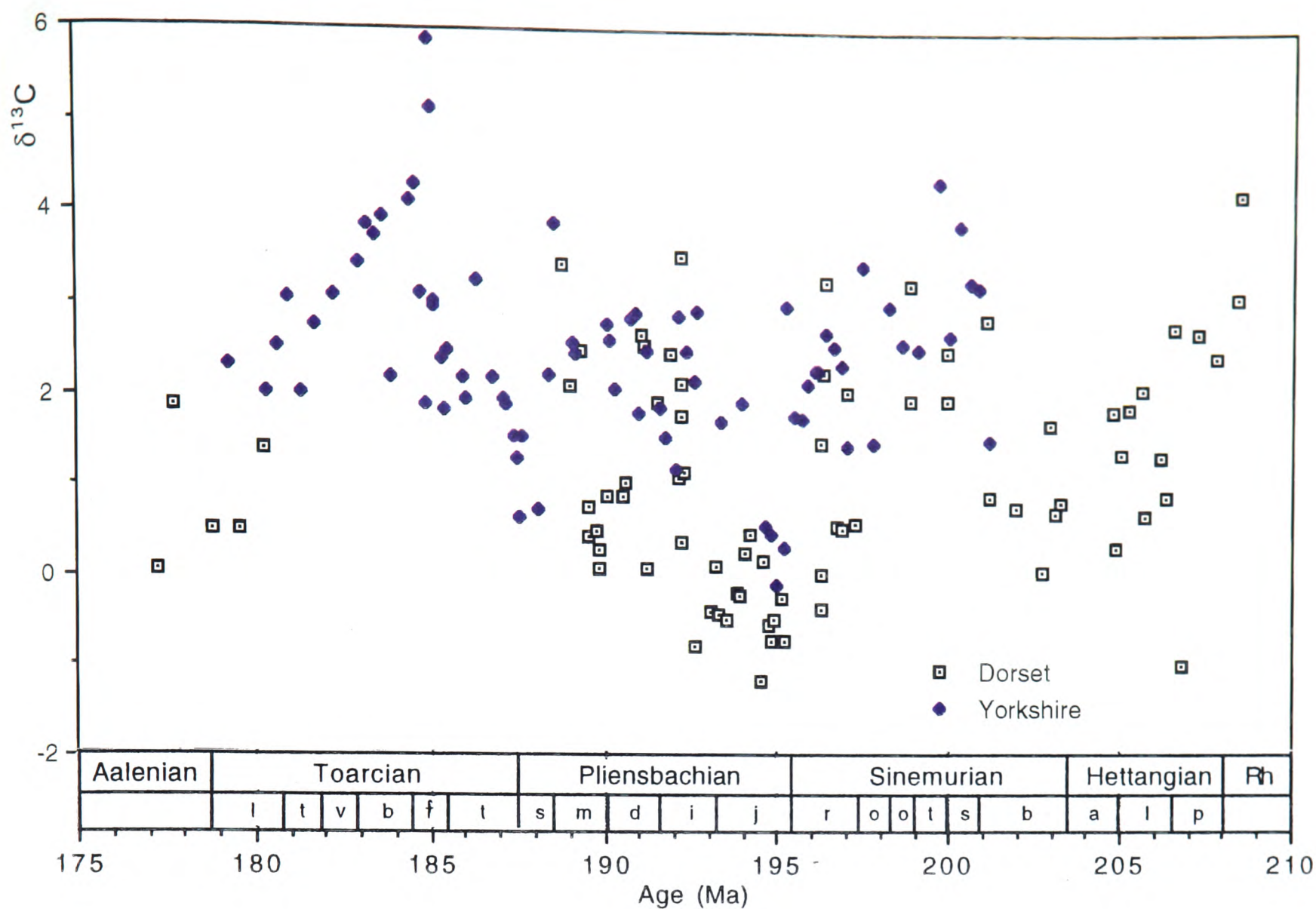


Figure 12.3a $\delta^{13}\text{C}$ data from the Dorset & Yorkshire Sections (Jones, 1992)

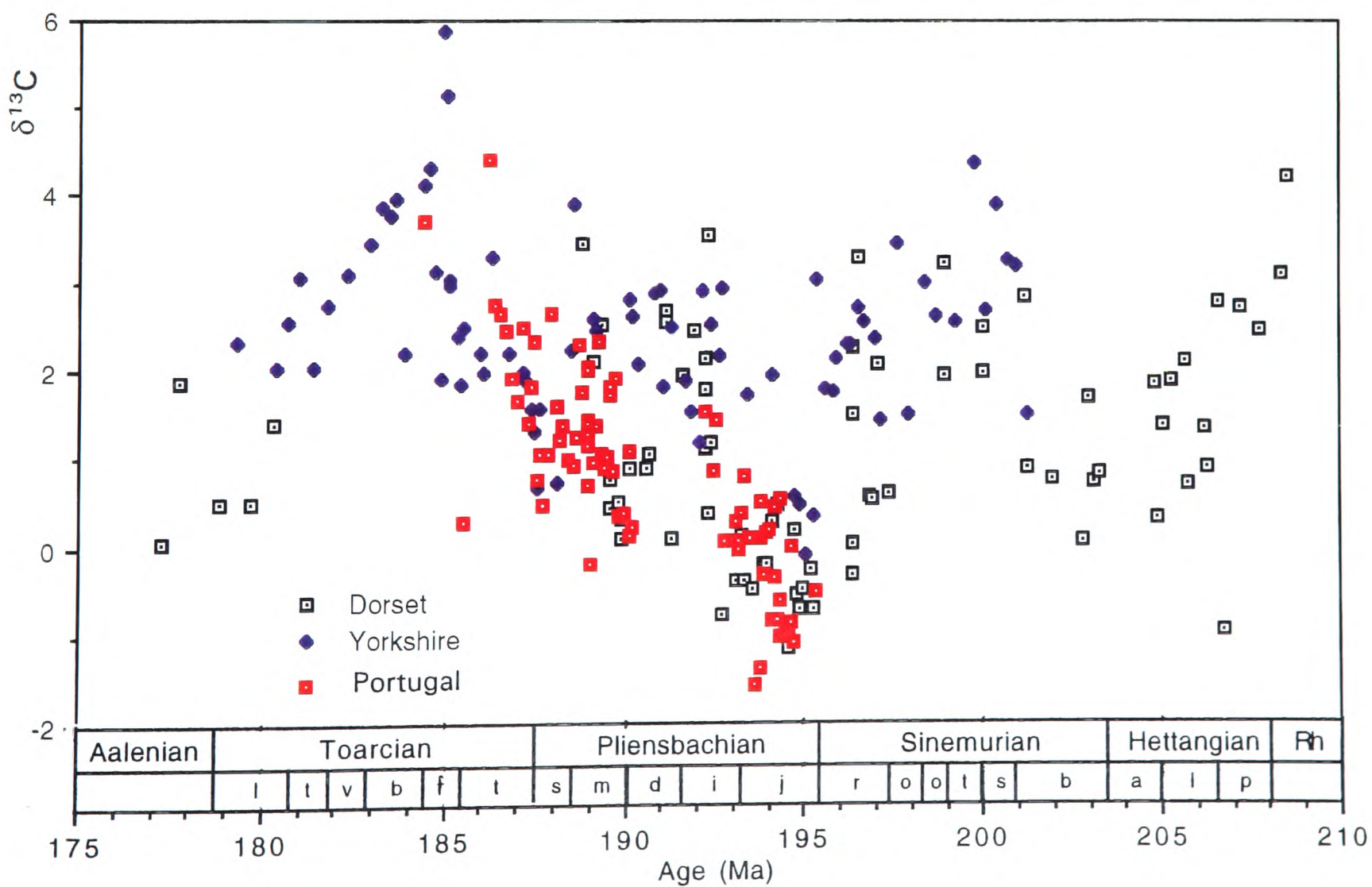


Figure 12.3b Data as figure 12.3a, plus data from Portugal (this study)

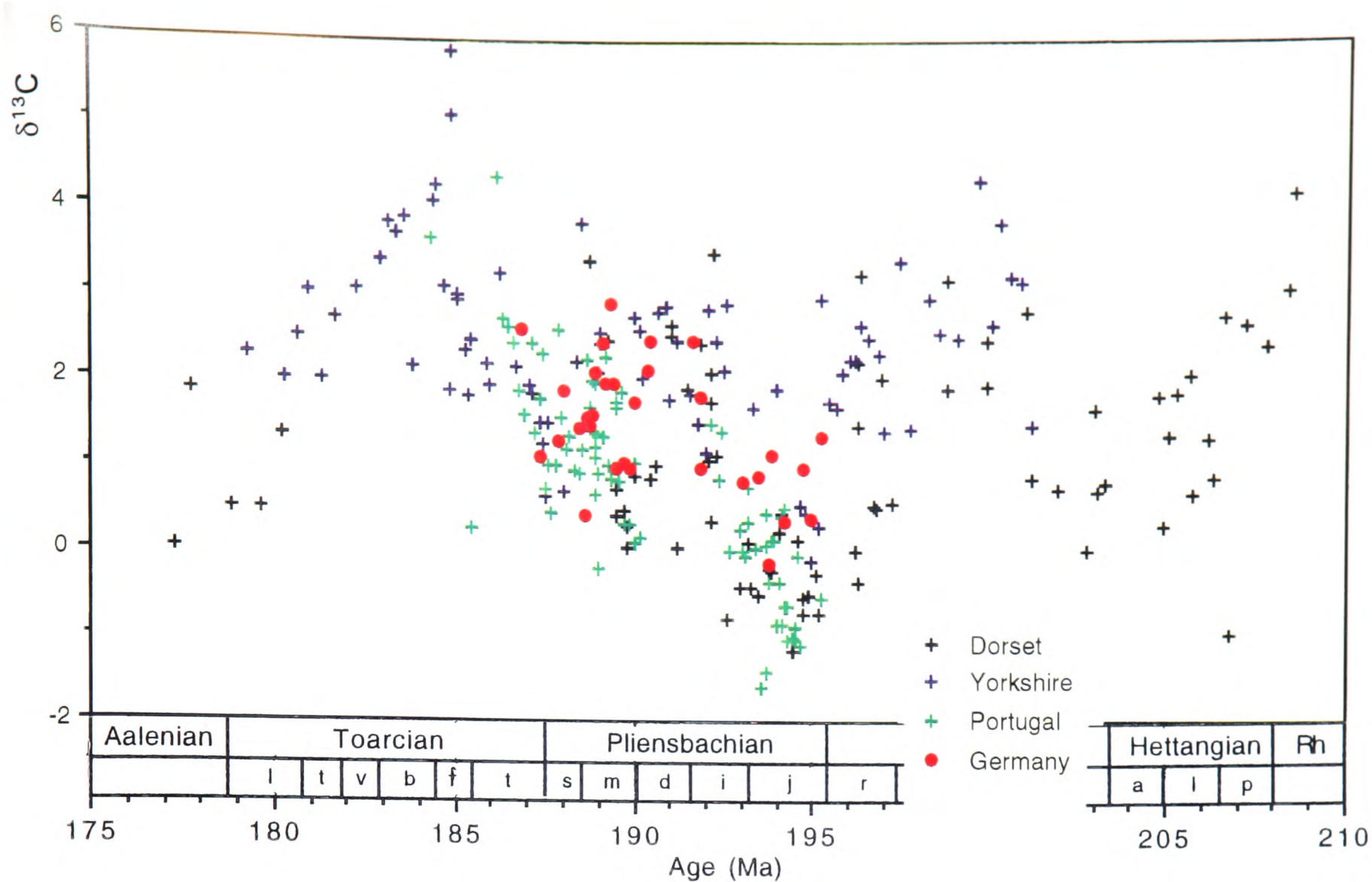


Figure 12.4a $\delta^{13}\text{C}$ data as figure 12.3b, plus data from Germany (this thesis)

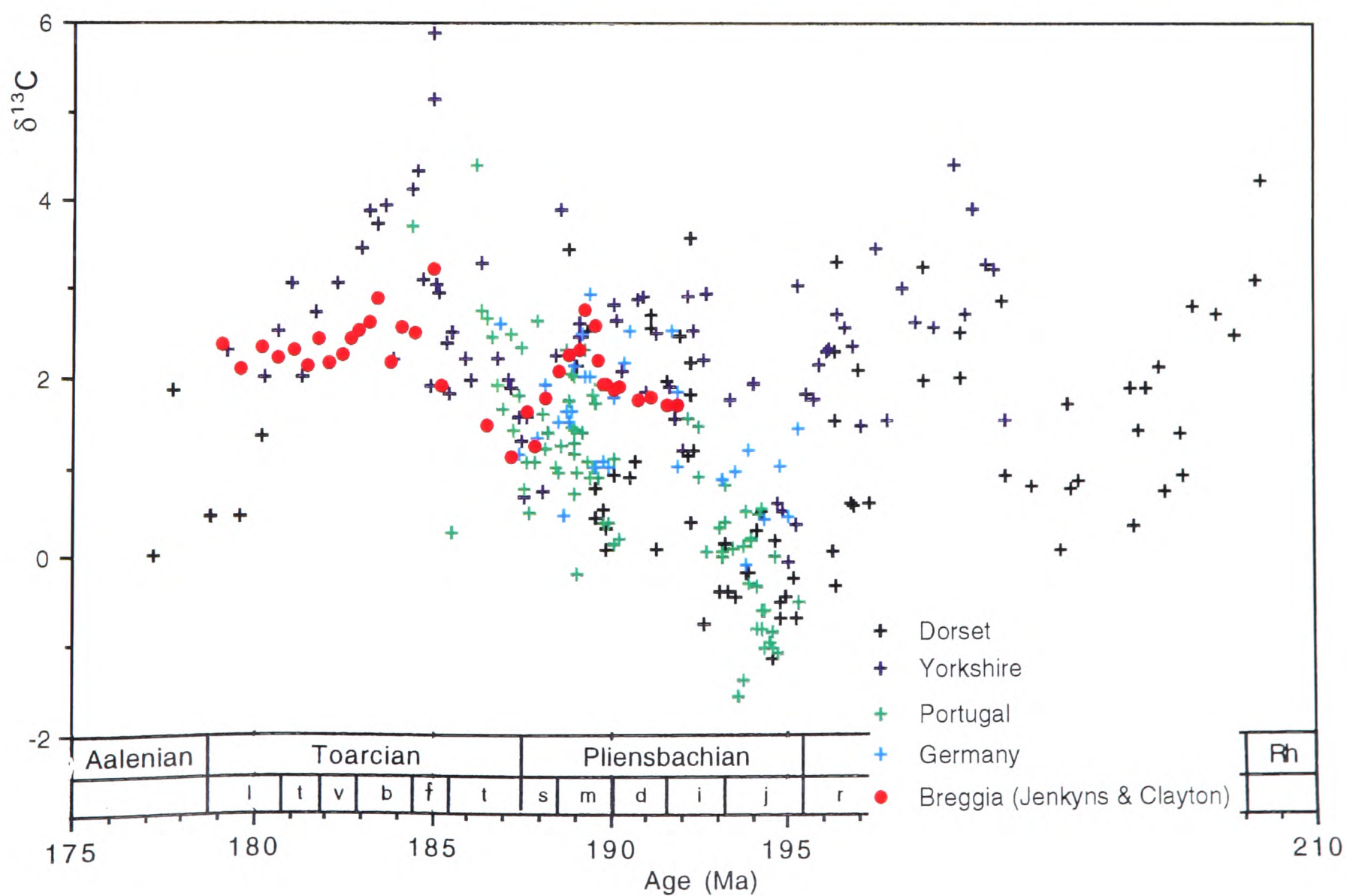


Figure 12.4b As figure 12.4a, plus data from the Breggia Gorge (Jenkyns & Clayton, 1986)

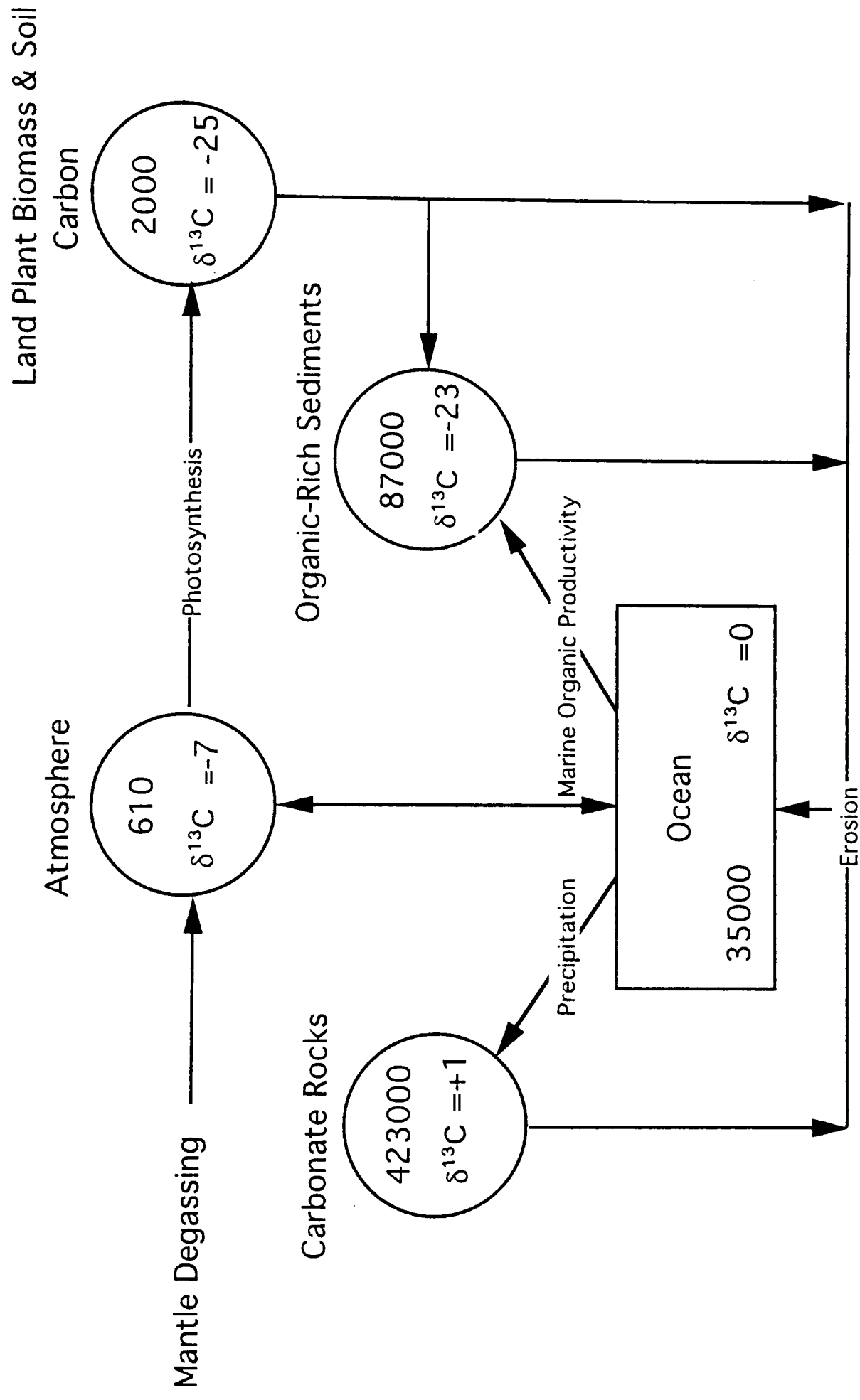


Figure 12.6 Approximate isotopic composition and mass (in 10^{15} g) of carbon in the principal reservoirs of the carbon cycle (from data in Arthur et al., 1983)

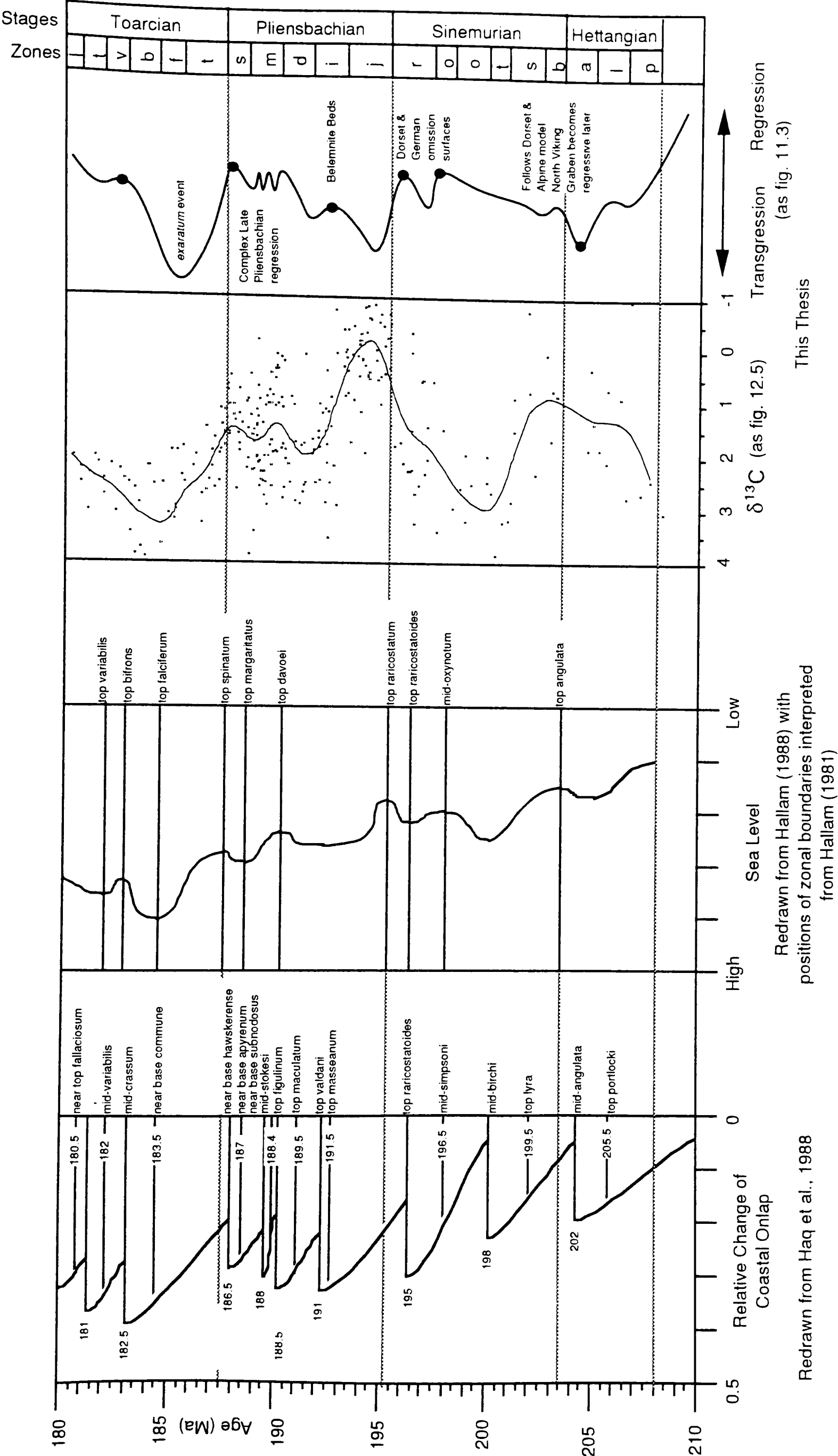


Figure 12.7 A comparison of various approaches to the stratigraphic signature of the Lower Jurassic

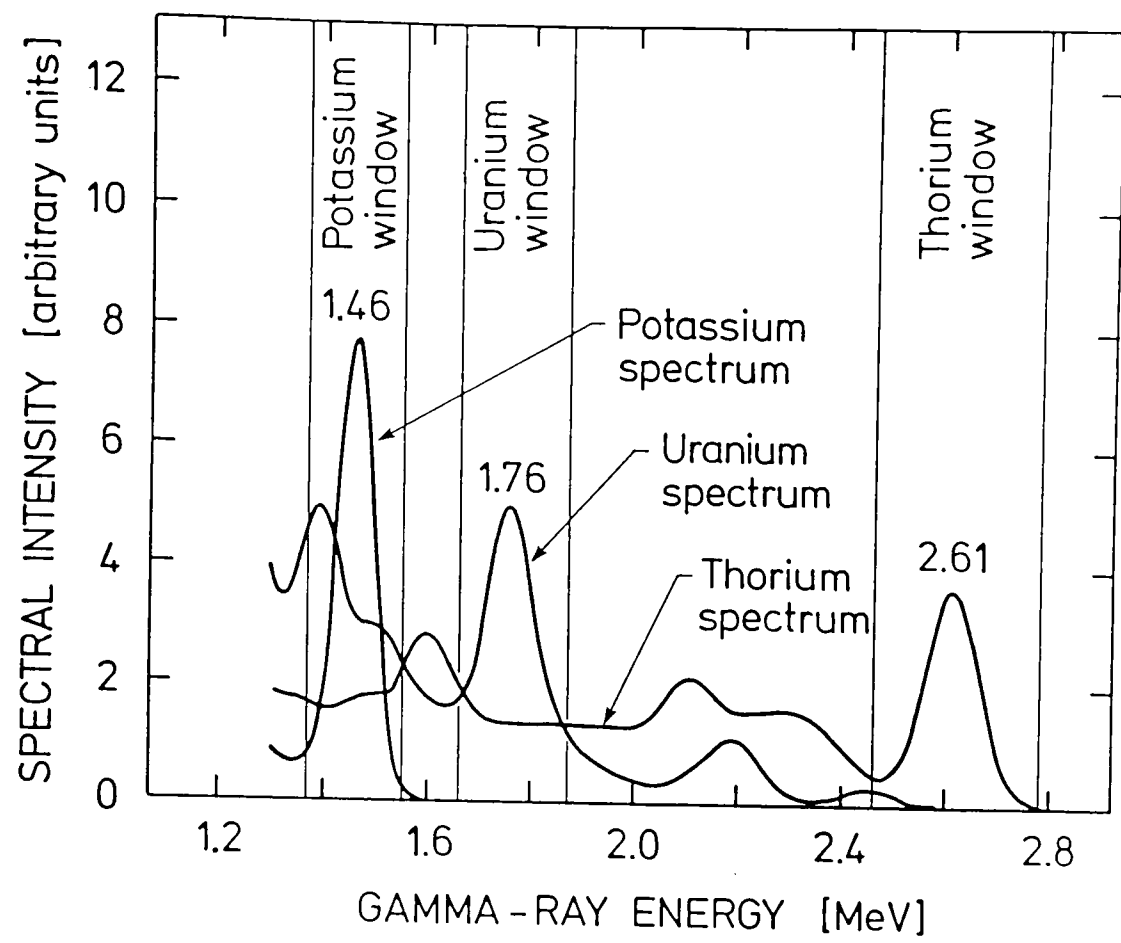


Figure A1.1a Scintillation spectra of Th, K & U from the ground (from Loveborg & Mose, 1987). Energy windows for radioelement assay using a gamma-spectrometer are shown.

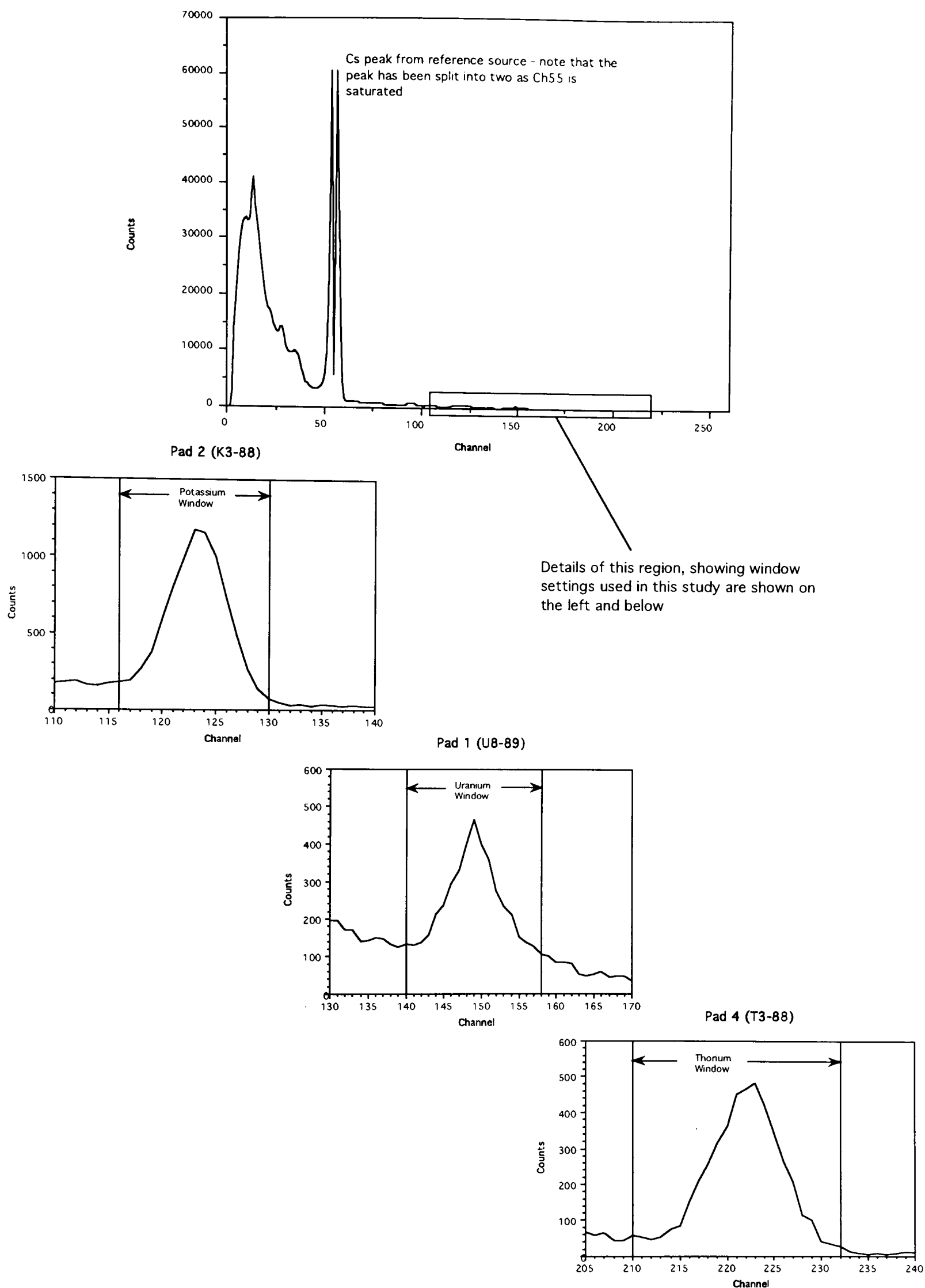


Figure A1.2 Calibration spectra obtained using "spiked" concrete blocks at the BGS calibration facility, Keyworth

C1	523	C6	482	C11	-2822
C2	22	C7	-429	C12	5
C3	6	C8	44	C13	-272
C4	4	C9	-29	C14	13272
C5	593	C10	4642	C15	

Figure A1.3a Calibration constants used for the Exploranium GR-256 spectrometer used in this study. C1-4 are the background counts, C5-14 are "stripping constants" used to correct for interference effects between elements.

	Total (ppm U)	K (%)	U (ppm)	Th (ppm)
Station 1A	18.7	3.0	3.5	14.5
10 readings at same station	18.3	2.9	8.8	12.6
	18.2	3.1	4.2	12.8
	18.1	2.8	3.6	13.8
	18.2	2.9	3.0	14.8
	18.4	2.8	4.6	12.7
	18.4	2.9	3.5	13.3
	18.5	3.1	3.0	14.0
	18.2	2.8	3.5	14.1
	18.4	2.8	4.1	14.1
Mean	18.34	2.91	3.68	13.67
Standard deviation	0.17	0.11	0.48	0.74
Percentage error (2σ)	1.84	7.81	26.27	10.79
Station 1B	17.0	2.6	4.3	11.2
10 readings at same station	17.0	2.6	3.6	12.8
	16.7	2.7	3.7	11.1
	16.8	2.7	2.8	13.1
	16.4	2.6	2.7	13.9
	16.8	2.8	3.1	12.3
	16.8	2.5	4.4	11.8
	16.7	2.7	3.5	12.4
	16.8	2.6	3.5	13.2
	17.1	2.7	3.6	11.6
Mean	16.81	2.65	3.52	12.34
Standard deviation	0.19	0.08	0.53	0.87
Percentage error (2σ)	2.22	6.08	30.04	14.7
Station 1A	18.34	2.91	3.68	13.67
Station 1B	16.81	2.65	3.52	12.34
Station 1C	16.0	2.70	2.70	13.10
Station 1D	15.2	2.20	4.00	11.10
Mean	16.59	2.62	3.48	12.55
Standard deviation	1.16	0.26	0.48	0.96
Percentage error (2σ)	14.00	19.79	27.61	15.33

Figure A1.3b Results of repeat measurements (4 minutes counting time) for four stations along the same bed (1A-1D) and for multiple measurements at the same station.

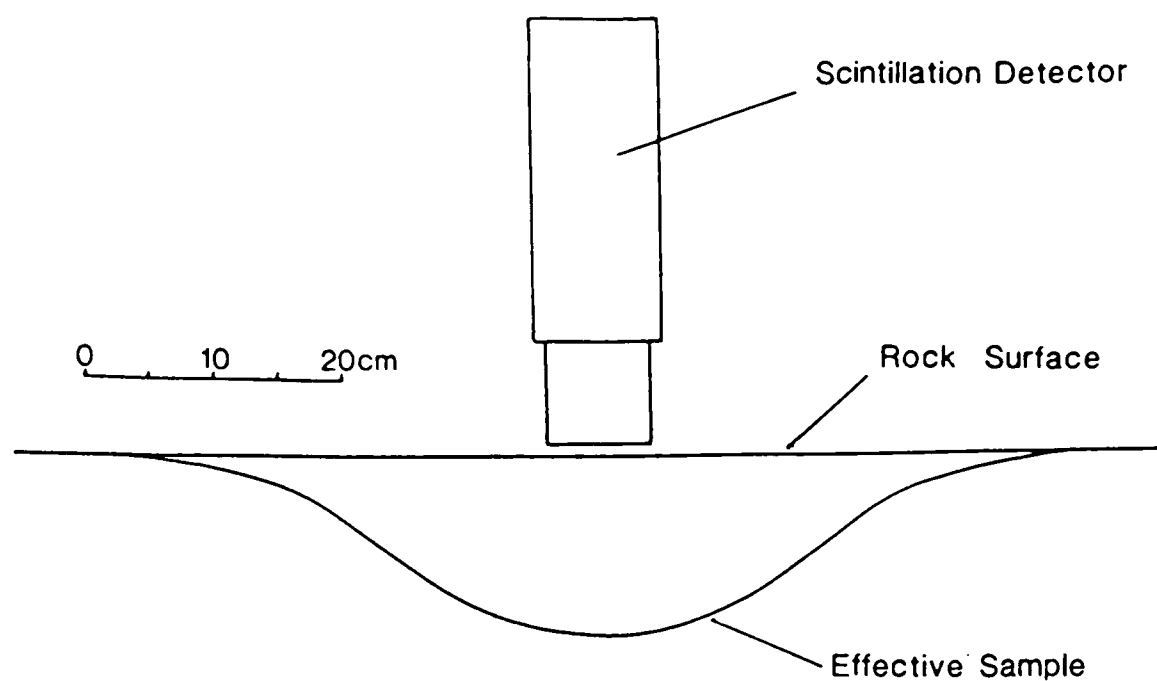


Figure A1.4a Size and shape of the effective sample for a spectrometer of the GR-256 type (after Løvborg et al. 1971)

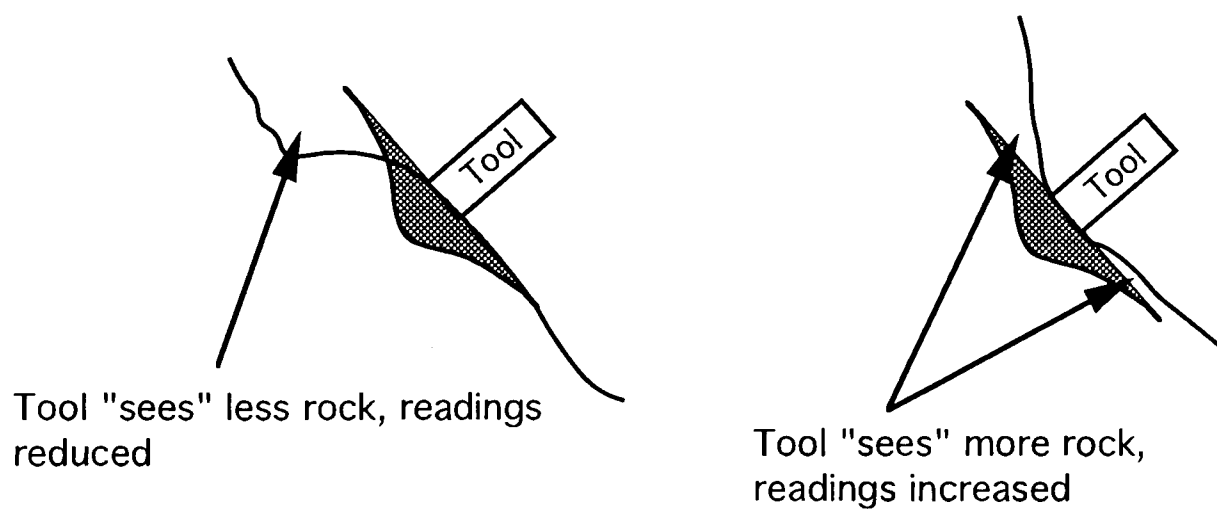


Figure A1.4b Effect of rock overhangs and cut-backs

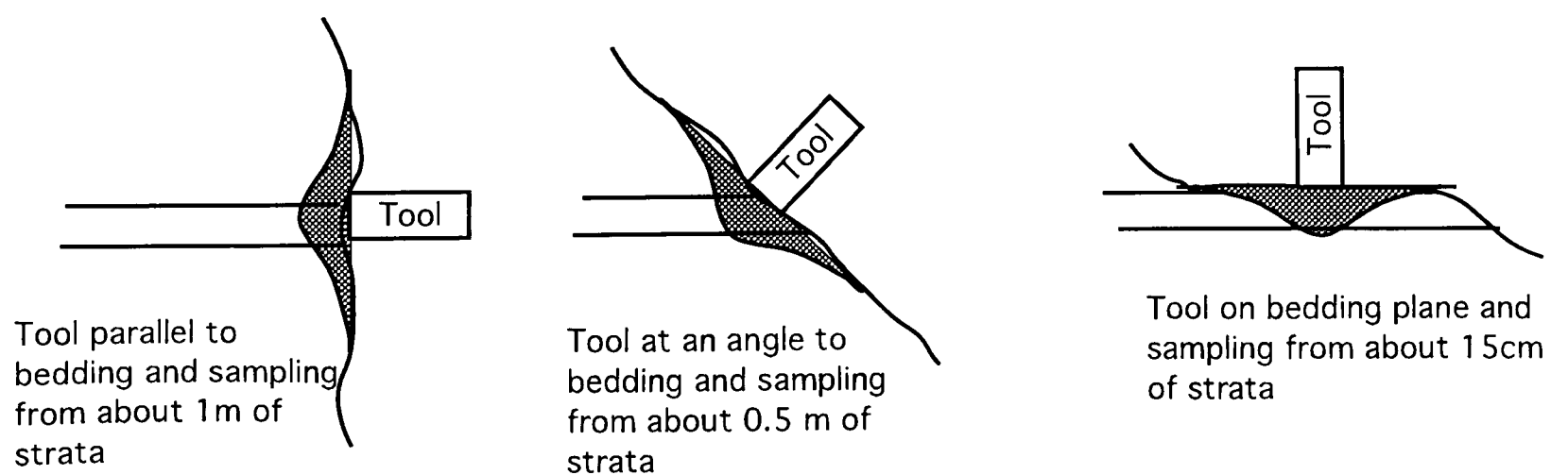


Figure A1.4c Effect on tool resolution of relationship between tool and bedding

Blue Lias

Station No	Total (ppm U)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
39 000	9 600	1 400	3 200	5 600	4 000	1 750
38 000	9 100	1 500	2 600	5 100	3 400	1 962
37 000	7 000	1 100	2 700	3 700	3 364	1 370
36 000	6 600	0 800	3 100	3 400	4 250	1 097
36 000	7 800	1 100	3 000	3 500	3 182	1 167
37 000	9 300	1 200	3 900	4 800	4 000	1 231
38 000	9 500	1 400	3 800	4 400	3 143	1 158
39 000	12 600	1 800	4 800	5 900	3 278	1 229
40 000	7 900	0 900	4 500	3 300	3 667	0 733
41 000	6 900	1 000	2 800	3 400	3 400	1 214
42 000	9 400	1 300	3 500	5 400	4 154	1 543
35 000	10 600	1 800	2 500	7 600	4 222	3 040
34 000	11 000	1 600	3 800	5 900	3 688	1 553
33 000	11 800	1 600	4 500	5 300	3 312	1 178
32 000	14 100	2 200	4 800	6 800	3 091	1 417
31 000	11 100	1 500	4 300	5 100	3 400	1 186
30 000	11 600	1 600	4 300	6 400	4 000	1 488
29 000	17 900	2 300	7 600	8 900	3 870	1 171
28 000	11 300	1 500	4 900	5 000	3 333	1 020
27 000	14 400	1 700	7 700	5 400	3 176	0 701
26 000	14 200	1 700	6 800	5 500	3 235	0 809
8 000	15 900	2 200	6 800	6 400	2 909	0 941
7 000	11 400	1 400	5 500	4 700	3 357	0 855
6 000	13 700	1 800	6 000	6 000	3 333	1 000
1 000	10 600	1 500	4 100	5 100	3 400	1 244
2 000	12 000	1 500	5 600	4 800	3 200	0 857
3 000	13 300	1 800	5 900	6 100	3 389	1 034
4 000	11 800	1 400	5 500	5 700	4 071	1 036
5 000	16 300	2 200	6 600	7 500	3 409	1 136
9 000	16 500	2 100	7 100	8 000	3 810	1 127
10 000	12 300	1 600	5 400	5 900	3 688	1 093
11 000	14 100	1 900	5 900	6 400	3 368	1 085
12 000	17 000	2 400	6 900	8 700	3 625	1 261
14 000	19 000	2 300	8 100	8 900	3 870	1 099
15 000	11 900	1 500	5 400	5 900	3 933	1 093
16 000	9 400	1 300	3 600	4 800	3 692	1 333
17 000	13 200	1 900	5 000	7 700	4 053	1 540
18 000	15 300	2 100	5 200	8 500	4 048	1 635
19 000	11 400	1 300	4 900	6 800	5 231	1 388
20 000	13 900	1 600	6 200	7 000	4 375	1 129
21 000	12 500	1 400	5 900	5 000	3 571	0 847
22 000	15 200	2 000	6 300	7 100	3 550	1 127
23 000	14 800	2 000	5 200	8 900	4 450	1 712
24 000	14 900	1 500	8 300	6 200	4 133	0 747
25 000	16 300	2 000	7 700	8 000	4 000	1 039

Shales-with-beef

Station No.	Total (ppm U)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
26 000	14 000	1 800	5 400	8 900	4 944	1 648
27 000	10 800	1 400	4 200	5 700	4 071	1 357
35 000	12 300	1 800	4 000	7 300	4 056	1 825
34 000	14 600	2 300	3 200	10 700	4 652	3 344
33 000	13 000	2 200	2 300	8 500	3 864	3 696
32 000	13 600	2 300	3 000	9 000	3 913	3 000
31 000	16 800	2 700	3 600	11 300	4 185	3 139
30 000	13 300	2 100	2 800	9 900	4 714	3 536
14 000	7 100	1 300	1 500	4 200	3 231	2 800
29 000	14 500	2 300	3 600	10 200	4 435	2 833
25 000	8 700	1 600	1 400	6 000	3 750	4 286
28 000	13 200	2 000	3 700	9 600	4 800	2 595
23 000	12 600	1 900	3 100	9 000	4 737	2 903
24 000	12 500	2 000	3 600	7 400	3 700	2 056
22 000	10 600	1 500	3 100	6 900	4 600	2 226
21 000	12 500	1 900	3 600	8 100	4 263	2 250
20 000	8 400	1 300	2 100	6 000	4 615	2 857
19 000	14 200	2 300	2 900	10 600	4 609	3 655
18 000	13 300	1 900	3 700	8 700	4 579	2 351
17 000	4 600	0 700	1 400	3 100	4 429	2 214
16 000	11 200	1 600	3 400	7 700	4 812	2 265
15 000	6 300	0 800	2 400	3 400	4 250	1 417
13 000	14 200	2 000	4 300	9 200	4 600	2 140
12 000	15 000	2 200	3 800	9 900	4 500	2 605
11 000	10 600	1 500	2 800	7 600	5 067	2 714
10 000	15 400	2 300	4 600	8 800	3 826	1 913
9 000	15 700	2 300	4 100	11 200	4 870	2 732
8 000	15 500	2 500	3 800	10 000	4 000	2 632
7 000	13 700	2 000	4 600	8 800	4 400	1 913
6 000	14 900	2 200	4 200	8 700	3 955	2 071
5 000	14 000	2 100	3 700	10 800	5 143	2 919
4 000	14 700	2 100	4 000	11 300	5 381	2 825
3 000	16 700	2 400	4 900	10 000	4 167	2 041
2 000	9 900	1 200	3 400	6 500	5 417	1 912
1 000	14 400	2 200	3 300	10 800	4 909	3 273

Figure A 1.5 Tabulation of spectral gamma-ray data from Dorset

Black Ven Marls						
Station	Total (ppm U)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
39	16 000	2 400	2 700	14 400	6 000	5 333
43	13 800	2 400	2 700	9 800	4 083	3 630
42	14 200	2 500	1 500	12 400	4 960	8 267
41	14 500	2 500	2 100	12 000	4 800	5 714
40	10 700	1 700	1 600	8 800	5 176	5 500
35	15 200	2 400	3 100	11 500	4 792	3 710
38	14 800	2 400	2 900	10 900	4 542	3 759
37	14 300	2 300	2 800	11 000	4 783	3 929
36	17 100	2 800	3 100	13 600	4 857	4 387
34	16 200	2 500	3 500	12 500	5 000	3 571
9	7 300	1 000	2 500	5 000	5 000	2 000
10	14 900	2 400	3 300	11 600	4 833	3 515
11	15 300	2 500	3 100	10 800	4 320	3 484
29	8 200	1 000	3 200	5 200	5 200	1 625
31	17 700	2 500	6 000	11 200	4 480	1 867
8	15 200	1 900	5 900	7 500	3 947	1 271
30	21 400	2 600	7 900	13 200	5 077	1 671
32	18 900	2 400	7 000	10 200	4 250	1 457
33	18 900	2 300	7 600	10 500	4 565	1 382
28	20 100	2 600	7 300	12 000	4 615	1 644
7	16 600	2 200	5 600	11 000	5 000	1 964
6	18 800	2 700	5 600	12 100	4 481	2 161
5	15 700	2 200	4 400	9 700	4 409	2 205
2	10 700	1 600	3 200	6 400	4 000	2 000
1	16 590	2 620	3 480	12 550	4 790	3 606
3	14 600	2 500	3 400	10 800	4 320	3 176
4	16 600	2 400	4 400	10 400	4 333	2 364
12B	15 400	2 200	5 100	10 500	4 773	2 059
13	16 000	2 600	3 000	12 800	4 923	4 267
14	16 500	2 600	2 800	14 100	5 423	5 036
27	16 400	2 700	3 300	11 200	4 148	3 394
21	17 700	2 900	3 300	12 800	4 414	3 879
22	16 800	2 900	1 900	14 200	4 897	7 474
23	16 700	2 700	2 600	13 400	4 963	5 154
24	15 400	2 500	2 800	12 300	4 920	4 393
25	15 300	2 600	3 500	11 100	4 269	3 171
26	15 200	2 600	2 500	11 000	4 231	4 400
19	16 800	2 700	2 800	13 600	5 037	4 857
20	19 000	3 000	3 600	15 300	5 100	4 250
18	19 100	3 000	3 600	14 800	4 933	4 111
17	18 300	2 900	3 200	15 400	5 310	4 812
15	18 900	2 400	6 900	12 200	5 083	1 768
16	11 000	1 600	4 100	6 600	4 125	1 610

Belemnite Marls						
Station No.	Total (ppm U)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
117	10.300	1.500	3.300	6.100	4.067	1.848
118	11.300	1.600	4.000	6.200	3.875	1.550
119	11.200	1.700	3.800	5.300	3.118	1.395
141	12.800	2.000	4.200	7.400	3.700	1.762
142	13.200	2.100	4.500	6.700	3.190	1.489
140	15.600	2.300	5.800	8.600	3.739	1.483
139	15.200	2.400	4.600	8.700	3.625	1.891
138	13.500	2.100	4.200	7.800	3.714	1.857
137	12.500	2.100	2.700	8.200	3.905	3.037
136	12.000	1.900	2.900	8.400	4.421	2.897
135	14.300	2.000	5.500	5.900	2.950	1.073
120	16.000	2.300	5.400	8.600	3.739	1.593
121	11.600	1.800	4.100	6.100	3.389	1.488
122	11.000	1.900	2.200	7.400	3.895	3.364
123	14.700	2.400	4.100	8.400	3.500	2.049
124	12.100	2.000	3.100	6.400	3.200	2.065
125	14.600	2.400	3.700	7.900	3.292	2.135
126	11.000	1.800	2.800	6.900	3.833	2.464
134	12.600	2.100	3.200	7.800	3.714	2.437
133	12.500	2.000	3.300	7.800	3.900	2.364
132	12.800	2.100	3.400	8.100	3.857	2.382
131	13.600	2.300	3.400	9.000	3.913	2.647
130	15.800	2.500	3.900	10.300	4.120	2.641
129	14.000	2.300	3.300	9.300	4.043	2.818
128	11.900	1.700	3.600	8.100	4.765	2.250
127	11.600	1.600	3.700	7.300	4.562	1.973

Figure A 1.5 Tabulation of spectral gamma-ray data from Dorset (cont'd)

Green Ammonite Beds

Station	Total (ppm U)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
65.000	13.000	1.700	4.700	8.000	4.706	1.702
66.000	18.300	2.900	4.000	14.900	5.138	3.725
67.000	18.700	2.900	4.600	13.100	4.517	2.848
68.000	15.800	2.600	3.300	13.600	5.231	4.121
69.000	15.000	2.400	2.900	11.300	4.708	3.897
70.000	15.900	2.500	3.500	12.300	4.920	3.514
71.000	16.100	2.500	3.700	11.600	4.640	3.135
72.000	15.600	2.400	2.700	13.100	5.458	4.852
73.000	15.500	2.400	2.900	13.100	5.458	4.517
74.000	14.700	2.200	3.600	11.900	5.409	3.306
75.000	15.900	2.500	3.000	13.300	5.320	4.433
52.000	19.300	3.100	3.400	15.900	5.129	4.676
76.000	15.300	2.500	3.400	11.000	4.400	3.235
51.000	17.700	3.000	3.400	13.200	4.400	3.882
77.000	16.700	2.600	3.000	14.400	5.538	4.800
50.000	18.900	3.000	3.400	15.700	5.233	4.618
78.000	17.000	2.600	4.000	13.400	5.154	3.350
49.000	18.700	3.200	3.500	15.000	4.688	4.286
48.000	19.100	3.100	3.500	14.900	4.806	4.257
47.000	17.900	2.900	3.100	14.500	5.000	4.677
46.000	19.400	3.300	3.100	16.500	5.000	5.323
45.000	19.600	3.100	4.200	15.100	4.871	3.595
43.000	17.800	3.000	3.200	13.700	4.567	4.281
44.000	16.700	2.600	3.000	14.100	5.423	4.700
64.000	18.100	3.000	3.800	14.000	4.667	3.684
63.000	16.500	2.700	2.700	13.900	5.148	5.148
62.000	18.100	3.100	2.800	13.500	4.355	4.821
61.000	17.400	2.900	2.900	14.400	4.966	4.966
59.000	19.100	3.300	2.700	16.100	4.879	5.963
60.000	18.700	3.200	2.800	14.500	4.531	5.179
58.000	19.300	3.200	3.200	14.000	4.375	4.375
57.000	18.100	2.900	3.500	13.800	4.759	3.943
56.000	18.300	3.100	2.300	16.000	5.161	6.957
55.000	20.000	3.300	3.800	15.300	4.636	4.026
54.000	15.900	2.600	3.200	11.900	4.577	3.719
53.000	19.100	3.200	3.000	16.500	5.156	5.500

Bridport sands

Station	Total (ppmU)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
191.000	10.300	1.900	1.600	6.500	3.421	4.062
190.000	11.100	2.100	2.200	6.800	3.238	3.091
189.000	13.200	2.400	2.300	8.700	3.625	3.783
188.000	12.900	2.300	2.400	9.100	3.957	3.792
187.000	13.600	2.300	2.400	9.600	4.174	4.000
186.000	10.700	1.900	1.900	7.200	3.789	3.789
185.000	13.900	2.600	1.900	9.300	3.577	4.895
184.000	13.700	2.400	2.800	8.800	3.667	3.143
183.000	14.700	2.300	2.900	10.200	4.435	3.517
182.000	11.900	1.800	2.600	8.600	4.778	3.308
179.000	11.600	2.200	1.900	7.000	3.182	3.684
180.000	14.700	2.700	2.200	9.700	3.593	4.409
181.000	14.200	2.400	2.500	9.800	4.083	3.920
193.000	10.900	1.600	2.700	7.600	4.750	2.815
178.000	10.900	1.600	2.400	7.000	4.375	2.917
177.000	13.200	2.000	2.900	10.600	5.300	3.655
176.000	10.500	1.600	3.000	7.400	4.625	2.467
175.000	10.600	1.700	2.300	7.300	4.294	3.174
174.000	11.600	2.100	2.400	7.200	3.429	3.000
173.000	13.600	2.300	2.900	8.800	3.826	3.034
172.000	11.300	1.900	2.400	6.600	3.474	2.750
171.000	11.900	2.100	2.200	8.300	3.952	3.773
170.000	10.200	1.900	1.400	7.400	3.895	5.286
169.000	13.300	2.500	1.900	9.200	3.680	4.842
168.000	11.500	2.000	2.200	8.100	4.050	3.682
167.000	14.900	2.700	2.600	9.400	3.481	3.615
166.000	11.800	2.200	2.100	7.400	3.364	3.524
165.000	14.100	2.600	2.400	9.200	3.538	3.833
164.000	14.100	2.400	2.600	10.500	4.375	4.038
163.000	14.000	2.700	2.000	9.300	3.444	4.650
162.000	14.100	2.500	2.500	9.800	3.920	3.920
161.000	13.300	2.300	2.400	9.100	3.957	3.792
160.000	13.600	2.600	2.300	8.400	3.231	3.652
204.000	13.400	2.300	2.500	9.000	3.913	3.600
202.000	12.900	2.200	2.800	8.400	3.818	3.000
201.000	14.700	2.700	2.700	9.700	3.593	3.593
203.000	14.800	2.500	3.000	9.900	3.960	3.300
200.000	13.100	2.200	3.100	8.400	3.818	2.710
199.000	14.100	2.300	3.600	9.100	3.957	2.528
198.000	14.900	2.000	5.000	10.100	5.050	2.020
197.000	11.900	1.800	3.100	8.600	4.778	2.774
196.000	13.600	2.100	4.000	8.300	3.952	2.075
195.000	12.300	1.500	5.300	6.400	4.267	1.208
194.000	10.000	0.600	6.600	4.600	7.667	0.697
192.000	10.800	0.400	8.200	3.500	8.750	0.427

Figure A 1.5 Tabulation of spectral gamma-ray data from Dorset (cont'd)

Calc/Siliceous Shales Data							
Station No.	m above top DB	Total (ppm U)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
176	-23.800	17.200	2.500	3.400	14.900	5.960	4.382
177	-22.900	16.900	2.700	2.300	15.600	5.778	6.783
178	-21.900	13.600	1.800	3.500	12.700	7.056	3.629
175	-19.000	15.000	2.100	3.100	13.900	6.619	4.484
174	-17.600	10.900	1.100	3.200	10.200	9.273	3.188
173	-11.100	23.800	3.300	5.100	19.100	5.788	3.745
172	-10.100	19.900	2.700	3.600	18.200	6.741	5.056
169	-9.300	21.400	2.900	4.400	20.000	6.897	4.545
171	-9.100	22.300	2.900	4.800	21.600	7.448	4.500
168	-8.300	24.000	3.600	4.100	22.600	6.278	5.512
170	-8.100	22.400	3.400	4.100	20.100	5.912	4.902
167	-7.300	24.100	3.600	4.800	20.500	5.694	4.271
166	-6.300	22.600	3.600	3.600	20.300	5.639	5.639
165	-5.300	22.200	3.400	3.400	20.700	6.088	6.088
164	-4.300	20.200	3.000	4.000	18.100	6.033	4.525
163	-3.200	22.900	3.500	4.800	18.800	5.371	3.917
97	-2.200	22.700	3.400	4.300	19.200	5.647	4.465
96	-1.200	17.500	2.300	4.300	16.200	7.043	3.767
95	0.000	14.900	1.800	3.700	13.600	7.556	3.676
94	0.500	24.800	3.700	4.500	22.000	5.946	4.889
93	1.500	22.500	3.200	4.900	19.100	5.969	3.898
92	2.500	20.600	2.700	4.000	20.800	7.704	5.200
86	4.000	17.000	2.200	3.800	16.700	7.591	4.395
87	5.000	21.400	3.100	3.700	21.000	6.774	5.676
88	5.900	19.000	2.400	3.900	20.000	8.333	5.128
89	6.900	20.800	2.900	4.000	18.000	6.207	4.500
90	7.900	21.100	3.100	3.700	18.900	6.097	5.108
91	8.900	21.300	3.100	3.400	20.300	6.548	5.971
162	9.600	26.400	4.000	4.300	25.300	6.325	5.884
161	10.300	25.000	3.500	5.100	23.300	6.657	4.569
160	11.200	23.500	3.300	4.900	21.100	6.394	4.306
159	12.200	26.400	3.800	5.700	24.900	6.553	4.368
158	13.200	22.900	3.100	4.100	22.500	7.258	5.488
157	14.200	24.600	3.700	4.600	21.400	5.784	4.652
156	15.200	19.400	2.300	4.500	19.200	8.348	4.267
155	16.100	21.700	2.900	4.400	20.300	7.000	4.614
154	17.100	23.100	3.100	5.000	21.100	6.806	4.220
153	18.200	24.900	3.500	4.600	23.400	6.686	5.087
152	19.000	20.400	2.600	4.000	20.200	7.769	5.050
151	20.000	22.700	3.100	4.700	20.700	6.677	4.404
150	21.000	23.000	3.200	4.700	21.000	6.562	4.468
149	22.000	24.100	3.700	4.700	19.500	5.270	4.149

Figure A1.6 Tabulation of spectral gamma-ray data from Yorkshire,
 "DB" is the Double Band

Pyritous/ Lr Ironst Data							
Station No	m above DB	Total (ppm U)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
151	20.000	22.700	3.100	4.700	20.700	6.677	4.404
150	21.000	23.000	3.200	4.700	21.000	6.562	4.468
149	22.000	24.100	3.700	4.700	19.500	5.270	4.149
200	23.200	23.000	3.500	3.500	19.900	5.686	5.686
148	24.200	24.900	3.500	5.400	20.600	5.886	3.815
201	25.300	24.700	3.400	5.300	21.900	6.441	4.132
202	26.300	25.100	3.200	6.900	19.800	6.188	2.870
203	27.300	25.800	3.300	7.500	21.500	6.515	2.867
204	28.600	25.400	3.400	5.600	22.500	6.618	4.018
1	29.100	23.500	3.200	6.300	18.400	5.750	2.921
205	29.800	25.200	3.500	5.900	22.800	6.514	3.864
2	30.100	24.800	3.500	5.200	21.500	6.143	4.135
206	30.700	25.400	3.600	5.300	21.900	6.083	4.132
3	31.100	24.900	3.400	5.600	21.500	6.324	3.839
207	31.700	26.200	3.700	5.900	21.800	5.892	3.695
4	32.300	25.000	3.500	5.200	22.300	6.371	4.288
5	33.300	23.600	3.400	4.800	20.500	6.029	4.271
6	34.100	22.300	3.200	4.600	18.900	5.906	4.109
7	35.100	24.000	3.400	4.600	21.600	6.353	4.696
8	35.900	23.800	3.400	5.300	20.700	6.088	3.906
9	36.900	25.000	3.700	5.300	21.600	5.838	4.075
10	37.700	23.500	3.300	4.700	22.400	6.788	4.766
11	38.300	24.700	3.500	5.500	20.200	5.771	3.673
12	38.900	22.300	3.100	4.300	21.100	6.806	4.907
23	39.200	22.000	3.200	4.300	21.700	6.781	5.047
22	40.200	24.900	3.500	5.100	21.000	6.000	4.118
21	41.200	23.100	3.300	5.200	19.300	5.848	3.712
20	42.200	27.000	3.800	5.700	24.600	6.474	4.316
19	43.200	26.300	3.600	5.400	24.200	6.722	4.481
18	43.900	27.500	3.800	5.600	25.100	6.605	4.482
17	44.600	26.900	3.600	6.900	23.100	6.417	3.348
16	45.600	25.800	3.500	6.100	22.000	6.286	3.607
15	46.600	26.000	3.600	5.900	23.500	6.528	3.983
14	47.400	19.800	2.700	4.200	18.800	6.963	4.476
13	47.900	15.400	2.200	2.900	14.700	6.682	5.069
24	48.900	24.400	3.300	4.900	22.500	6.818	4.592
25	49.800	22.100	3.000	5.200	19.100	6.367	3.673
26	50.800	23.500	3.200	5.200	20.400	6.375	3.923
27	52.000	21.200	2.600	5.600	18.700	7.192	3.339
28	53.100	22.000	2.800	5.300	19.500	6.964	3.679
29	54.200	21.600	3.000	4.500	19.400	6.467	4.311
30	55.300	23.200	3.100	4.300	22.100	7.129	5.140
31	56.400	24.100	3.200	4.700	23.200	7.250	4.936
32	57.500	23.600	3.200	5.000	21.900	6.844	4.380
33	58.700	26.500	3.400	5.500	26.100	7.676	4.745
34	59.700	26.100	3.300	5.700	23.900	7.242	4.193
35	60.700	24.100	3.200	6.200	20.100	6.281	3.242
36	61.700	24.700	3.300	5.500	23.400	7.091	4.255
98	62.700	25.000	3.300	5.400	21.700	6.576	4.019
99	63.700	25.300	3.400	5.500	22.600	6.647	4.109
100	64.700	24.000	3.200	5.400	22.400	7.000	4.148
101	65.700	23.700	3.200	5.300	21.100	6.594	3.981
108	67.400	23.100	3.000	5.700	21.100	7.033	3.702
107	68.400	21.500	2.900	4.800	19.500	6.724	4.063
106	68.900	22.000	3.000	4.800	21.400	7.133	4.458
105	69.400	21.600	2.800	4.600	21.500	7.679	4.674
104	70.300	23.300	3.000	6.100	18.700	6.233	3.066
103	71.300	22.600	3.100	5.700	18.600	6.000	3.263
102	72.300	21.000	3.100	4.800	17.400	5.613	3.625

Figure A1.6 Tabulation of spectral gamma-ray data from Yorkshire,
 "DB" is the Double Band (cont'd)

Upper Irnst. Shales Data							
Station No	m above DB	Total (ppm U)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
224	73.500	21.800	3.100	4.800	18.200	5.871	3.792
225	74.900	19.600	2.900	3.800	17.400	6.000	4.579
226	76.000	20.100	3.000	3.700	17.400	5.800	4.703
223	77.300	23.600	3.000	5.700	19.600	6.533	3.439
227	78.500	18.600	2.600	4.000	16.300	6.269	4.075
228	79.400	18.800	2.600	3.600	18.200	7.000	5.056
229	83.400	20.000	3.200	3.100	17.800	5.563	5.742
222	84.500	20.600	3.000	3.500	20.900	6.967	5.971
221	85.300	20.200	3.300	3.100	18.100	5.485	5.839
220	86.300	18.800	2.800	3.300	16.700	5.964	5.061
219	87.300	19.300	3.000	3.200	16.200	5.400	5.062
218	88.300	19.900	3.200	3.200	17.700	5.531	5.531
217	89.300	17.200	2.600	2.700	15.200	5.846	5.630
216	90.300	18.200	3.000	2.700	16.500	5.500	6.111
215	91.300	20.600	3.300	3.000	17.800	5.394	5.933
127	92.300	20.400	3.000	3.100	20.200	6.733	6.516
126	93.300	19.300	2.800	3.700	17.500	6.250	4.730
125	94.100	19.100	3.000	3.400	16.500	5.500	4.853
124	95.100	19.400	3.000	3.400	15.900	5.300	4.676
123	96.200	21.200	3.300	4.200	17.600	5.333	4.190
122	97.200	19.300	2.900	3.600	17.500	6.034	4.861
121	98.200	16.000	2.300	3.100	14.900	6.478	4.806
120	99.200	17.300	2.600	2.900	15.700	6.038	5.414
119	100.300	20.600	3.000	3.900	20.000	6.667	5.128
118	101.300	19.200	3.000	3.300	16.300	5.433	4.939
117	102.300	18.400	2.800	3.100	17.000	6.071	5.484
116	103.300	19.500	2.900	3.700	16.500	5.690	4.459
115	104.300	20.800	3.100	4.000	17.700	5.710	4.425
114	105.300	19.800	3.000	4.100	15.000	5.000	3.659
113	106.300	19.200	2.900	3.600	16.700	5.759	4.639
112	107.300	17.000	2.400	4.300	13.400	5.583	3.116
111	108.300	18.400	2.500	4.100	16.200	6.480	3.951
110	109.300	17.200	2.300	4.100	15.000	6.522	3.659
109	110.300	12.600	1.600	2.200	12.700	7.938	5.773

Staithes Sst. Data							
Station No.	m above DB	Total (ppm U)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
230	111.300	16.900	2.300	3.700	14.900	6.478	4.027
231	112.300	17.600	2.400	4.100	15.600	6.500	3.805
232	113.300	19.100	2.600	4.400	17.500	6.731	3.977
233	114.500	21.700	3.300	3.900	17.200	5.212	4.410
234	115.500	17.300	2.400	3.300	16.500	6.875	5.000
235	116.500	19.400	2.900	3.800	16.600	5.724	4.368
236	117.500	19.300	2.700	3.900	17.100	6.333	4.385
237	117.500	17.500	2.600	3.900	14.100	5.423	3.615
238	118.400	17.900	2.800	3.100	16.200	5.786	5.226
239	119.300	17.800	2.500	3.700	15.500	6.200	4.189
240	120.200	15.700	1.900	3.500	14.200	7.474	4.057
241	120.900	13.300	1.600	3.200	12.100	7.562	3.781
242	121.300	13.200	1.900	2.400	10.600	5.579	4.417
243	122.300	20.200	2.600	4.500	18.800	7.231	4.178
244	123.400	18.100	2.600	3.700	15.000	5.769	4.054
245	124.400	17.300	2.200	4.000	16.200	7.364	4.050
246	125.400	13.700	1.700	3.500	12.300	7.235	3.514
247	126.400	17.200	2.000	4.100	17.500	8.750	4.268
248	127.400	17.400	2.100	3.800	17.600	8.381	4.632
249	128.900	16.100	2.000	3.300	16.200	8.100	4.909
250	129.900	18.600	2.300	3.900	17.100	7.435	4.385
251	130.900	20.000	2.700	4.300	16.700	6.185	3.884
252	131.900	19.200	2.400	4.400	17.600	7.333	4.000
253	132.900	17.700	2.500	3.500	16.300	6.520	4.657
254	134.000	14.900	2.100	2.700	13.500	6.429	5.000
255	135.000	17.000	2.400	3.400	15.000	6.250	4.412

Figure A1.6 Tabulation of spectral gamma-ray data from Yorkshire,
 "DB" is the Double Band(cont'd)

Cleveland Ironst. Data							
Station No	m above DB	Total (ppm U)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
256	136.100	9.700	1.100	2.400	8.500	7.727	3.542
257	137.400	21.400	3.100	3.900	19.500	6.290	5.000
258	138.400	20.300	2.900	3.900	17.600	6.069	4.513
259	139.100	20.400	2.800	4.400	18.500	6.607	4.205
85	140.100	21.800	3.300	2.800	20.200	6.121	7.214
84	141.100	22.000	3.200	4.200	19.200	6.000	4.571
83	142.100	19.000	2.800	3.800	16.700	5.964	4.395
82	143.100	19.300	2.900	3.300	18.200	6.276	5.515
81	144.100	11.500	1.600	2.900	9.800	6.125	3.379
80	145.100	21.300	3.100	3.700	20.300	6.548	5.486
79	146.100	21.000	3.200	3.300	19.100	5.969	5.788
78	147.500	22.600	3.300	4.200	20.800	6.303	4.952
77	148.500	18.200	2.900	2.900	15.800	5.448	5.448
76	149.500	19.700	2.900	3.800	17.900	6.172	4.711
75	150.500	24.000	3.200	4.300	24.900	7.781	5.791
74	151.100	14.900	1.400	3.600	18.000	12.857	5.000
73	151.400	20.500	2.800	3.800	19.900	7.107	5.237
72	152.400	19.300	2.400	4.100	19.800	8.250	4.829
71	153.400	21.300	2.800	4.400	20.200	7.214	4.591
70	154.400	19.300	2.900	3.600	17.900	6.172	4.972
69	155.400	19.700	3.200	3.200	17.400	5.438	5.438
68	156.400	18.200	2.700	3.600	15.100	5.593	4.194
67	157.400	20.800	3.100	3.700	18.900	6.097	5.108
66	158.400	19.700	3.000	3.600	17.900	5.967	4.972
65	159.200	16.300	2.300	3.000	16.200	7.043	5.400
64	160.200	17.000	2.400	3.600	16.300	6.792	4.528
63	161.000	10.600	1.300	2.300	10.100	7.769	4.391
62	161.900	18.700	2.700	3.300	17.000	6.296	5.152

Gy Shales/Jet Rock Data							
Station	m above DB	Total (ppmU)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
62.000	161.900	18.700	2.700	3.300	17.000	6.296	5.152
61.000	162.900	20.100	2.900	3.900	18.000	6.207	4.615
60.000	163.900	22.500	3.600	3.800	19.900	5.528	5.237
59.000	164.900	22.300	3.500	3.700	20.100	5.743	5.432
58.000	165.900	21.700	3.200	3.500	21.300	6.656	6.086
57.000	167.000	20.100	2.900	3.500	19.100	6.586	5.457
56.000	167.800	24.400	3.600	3.700	21.800	6.056	5.892
55.000	168.600	24.200	3.600	4.200	22.600	6.278	5.381
54.000	169.500	24.700	3.700	4.000	23.500	6.351	5.875
53.000	170.300	25.200	3.800	4.600	23.700	6.237	5.152
52.000	171.200	24.900	3.700	4.300	22.200	6.000	5.163
51.000	172.000	26.200	3.900	5.300	22.900	5.872	4.321
50.000	173.000	22.500	3.200	4.600	20.200	6.312	4.391
49.000	174.000	21.700	3.000	3.800	20.400	6.800	5.368
45.000	174.800	24.300	3.300	6.900	17.700	5.364	2.565
48.000	175.000	24.900	3.500	5.100	21.100	6.029	4.137
47.000	175.900	27.800	3.800	7.300	23.700	6.237	3.247
46.000	176.900	23.600	3.100	6.400	19.800	6.387	3.094
44.000	178.600	24.400	3.300	7.000	17.400	5.273	2.486
43.000	179.500	22.300	2.800	7.800	14.900	5.321	1.910
42.000	180.500	21.200	2.800	6.700	15.400	5.500	2.299
37.000	181.500	20.800	3.000	5.600	16.700	5.567	2.982
38.000	182.500	20.100	2.600	6.100	15.800	6.077	2.590
39.000	183.500	20.800	2.500	7.600	13.500	5.400	1.776
40.000	184.500	24.900	3.400	7.400	19.600	5.765	2.649
41.000	185.500	26.500	3.700	7.900	18.000	4.865	2.278

Figure A1.6 Tabulation of spectral gamma-ray data from Yorkshire, "DB" is the Double Band (cont'd)

Bitum/Alum Shales Data							
Station	m above DB	Total (ppmU)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
179.000	192.250	21.600	3.200	4.800	17.000	5.312	3.542
180.000	193.250	21.600	2.800	6.900	15.100	5.393	2.188
181.000	194.250	25.800	3.500	7.800	18.200	5.200	2.333
182.000	195.250	26.500	3.500	8.000	20.400	5.829	2.550
183.000	196.250	27.000	3.800	7.100	21.100	5.553	2.972
184.000	197.200	24.600	3.300	6.300	20.400	6.182	3.238
185.000	198.200	25.900	3.600	6.200	18.400	5.111	2.968
186.000	199.200	25.100	3.800	5.000	21.500	5.658	4.300
187.000	200.200	25.700	3.900	4.300	22.100	5.667	5.140
188.000	201.200	26.400	3.700	6.100	22.400	6.054	3.672
189.000	202.700	26.700	4.100	5.500	22.300	5.439	4.055
190.000	203.900	22.700	3.200	4.900	19.300	6.031	3.939
191.000	204.900	23.900	3.400	5.000	20.400	6.000	4.080
192.000	205.900	24.600	3.600	5.100	20.300	5.639	3.980
193.000	206.900	23.600	3.500	4.400	20.000	5.714	4.545
194.000	207.900	23.600	3.700	4.800	21.400	5.784	4.458
195.000	209.000	22.800	3.200	6.200	17.600	5.500	2.839
196.000	210.300	23.900	3.300	5.700	20.500	6.212	3.596
197.000	211.300	24.200	3.500	4.500	21.900	6.257	4.867
198.000	212.300	22.500	3.300	4.400	19.200	5.818	4.364
199.000	213.300	19.400	2.700	3.700	17.600	6.519	4.757
208.000	216.300	20.400	3.000	3.400	19.000	6.333	5.588
209.000	217.300	22.200	3.300	4.100	19.200	5.818	4.683
210.000	218.300	24.100	3.500	4.100	21.500	6.143	5.244
211.000	219.300	25.000	3.600	4.800	22.600	6.278	4.708
212.000	220.300	24.300	3.500	4.500	22.600	6.457	5.022
213.000	221.800	26.400	4.000	4.500	23.200	5.800	5.156
293.000	225.200	20.700	3.100	3.300	19.000	6.129	5.758
292.000	226.200	22.700	3.300	2.800	22.800	6.909	8.143
291.000	227.200	21.800	3.200	3.800	19.100	5.969	5.026
290.000	228.200	23.500	3.400	3.900	20.600	6.059	5.282
289.000	229.200	24.500	3.600	4.300	21.400	5.944	4.977
288.000	230.500	24.600	3.700	4.100	20.500	5.541	5.000
287.000	231.500	24.600	3.400	4.900	22.300	6.559	4.551
286.000	232.500	25.200	3.600	4.200	24.800	6.889	5.905
262.000	233.500	25.100	3.600	4.700	21.800	6.056	4.638

Cement/Peak Shales Data							
Station	m above DB	Total (ppmU)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
261.000	234.500	23.900	3.600	4.200	20.900	5.806	4.976
260.000	235.500	22.500	3.200	4.800	20.500	6.406	4.271
265.000	236.700	24.200	3.400	4.700	22.300	6.559	4.745
214.000	237.500	24.500	3.700	4.400	22.100	5.973	5.023
263.000	238.500	22.700	3.100	4.700	20.300	6.548	4.319
264.000	239.500	24.100	3.700	3.800	22.200	6.000	5.842
280.000	240.500	22.700	3.300	4.900	19.000	5.758	3.878
281.000	241.500	22.900	3.200	4.100	22.300	6.969	5.439
282.000	242.500	22.900	3.200	4.400	21.000	6.562	4.773
283.000	243.500	25.300	3.500	4.200	22.900	6.543	5.452
284.000	244.500	23.800	3.400	4.200	21.800	6.412	5.190
285.000	245.500	24.000	3.300	4.400	22.200	6.727	5.045
279.000	249.600	24.200	3.400	5.300	20.400	6.000	3.849
278.000	250.600	25.300	3.800	4.900	21.100	5.553	4.306
277.000	251.600	25.100	3.600	4.800	23.200	6.444	4.833
276.000	252.600	23.200	3.300	4.300	21.800	6.606	5.070
275.000	253.600	22.200	3.200	3.800	21.200	6.625	5.579
274.000	254.600	26.300	3.900	5.200	22.800	5.846	4.385
273.000	255.600	24.300	3.500	4.500	20.100	5.743	4.467
272.000	257.600	24.700	3.600	3.800	24.400	6.778	6.421
271.000	258.600	24.100	3.500	4.200	20.500	5.857	4.881
270.000	259.600	22.900	3.400	4.100	19.700	5.794	4.805
269.000	260.600	22.900	3.200	4.600	20.500	6.406	4.457
268.000	261.600	24.900	3.400	4.800	24.000	7.059	5.000
267.000	262.600	24.200	3.500	4.400	23.500	6.714	5.341

Figure A1.6 Tabulation of spectral gamma-ray data from Yorkshire,

"DB" is the Double Band (cont'd)

Peniche Gamma Data D							
Above Base(m)	Station No	Total (ppmU)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
71.30	108	12.800	2.400	2.500	6.200	2.583	2.480
73.20	107	6.600	1.200	1.400	2.900	2.417	2.071
74.50	106	11.100	2.200	1.500	7.700	3.500	5.133
75.60	105	10.900	2.000	2.400	6.300	3.150	2.625
76.75	104	10.200	1.900	2.100	5.700	3.000	2.714
78.10	103	10.500	2.000	2.100	5.700	2.850	2.714
79.30	102	12.400	2.300	2.500	7.300	3.174	2.920
80.75	101	13.100	2.500	2.200	7.500	3.000	3.409
81.25	100	11.800	2.100	3.400	5.100	2.429	1.500
82.75	99	9.100	1.600	2.000	4.500	2.812	2.250
83.60	98	13.900	2.600	2.700	8.000	3.077	2.963
84.55	97	13.300	2.500	2.700	6.900	2.760	2.556
85.65	96	13.000	2.500	2.400	7.500	3.000	3.125
86.60	95	14.300	2.800	2.500	8.000	2.857	3.200
87.40	81	10.700	2.100	2.100	5.900	2.810	2.810
87.80	80	10.900	2.200	1.900	6.200	2.818	3.263
88.20	79	13.300	2.500	2.500	7.500	3.000	3.000
89.35	78	12.400	2.400	2.400	6.000	2.500	2.500
91.25	77	15.200	3.000	2.300	8.400	2.800	3.652
92.55	76	15.100	2.900	2.700	8.300	2.862	3.074
93.15	75	14.200	2.700	3.100	7.600	2.815	2.452
93.95	74	16.500	3.300	2.400	9.800	2.970	4.083
95.50	73	14.600	2.800	2.400	8.000	2.857	3.333
96.85	72	17.400	3.500	3.000	8.900	2.543	2.967
98.40	71	14.700	2.900	2.400	8.700	3.000	3.625
99.20	69	14.700	2.800	3.200	7.300	2.607	2.281
99.80	70	17.700	3.500	2.800	9.000	2.571	3.214
100.40	68	15.600	3.000	2.700	8.400	2.800	3.111
101.25	67	11.300	2.200	1.600	6.100	2.773	3.812
102.80	66	14.700	3.000	2.500	7.900	2.633	3.160
103.80	65	13.800	2.600	2.800	8.000	3.077	2.857
104.80	64	15.100	3.000	2.800	7.900	2.633	2.821
105.75	63	13.900	2.700	2.100	7.800	2.889	3.714
106.90	62	14.900	3.000	2.700	7.300	2.433	2.704
108.85	61	7.000	1.400	1.300	2.900	2.071	2.231
109.80	82	9.500	1.800	1.900	4.900	2.722	2.579
111.20	83	12.600	2.400	2.500	7.100	2.958	2.840
111.90	84	12.400	2.400	2.600	5.900	2.458	2.269
112.55	85	11.800	2.100	2.500	5.200	2.476	2.080
113.30	86	12.800	2.600	2.400	6.600	2.538	2.750
114.46	87	14.800	2.700	3.500	7.900	2.926	2.257
116.02	88	13.000	2.500	2.900	5.600	2.240	1.931
117.30	89	12.500	2.400	2.100	6.200	2.583	2.952
118.85	90	13.400	2.400	2.900	6.500	2.708	2.241
120.30	91	9.900	1.700	2.300	4.600	2.706	2.000
121.20	92	12.000	2.100	3.200	5.600	2.667	1.750
122.20	93	11.400	2.000	2.800	5.900	2.950	2.107
123.30	94	12.200	2.300	2.300	6.400	2.783	2.783
124.95	60	15.500	3.100	3.100	8.100	2.613	2.613
125.80	110	10.600	1.900	2.200	5.100	2.684	2.318
125.95	59	14.200	2.800	2.500	6.800	2.429	2.720
126.95	58	14.100	2.800	2.100	7.500	2.679	3.571
127.10	111	11.300	2.100	2.400	5.500	2.619	2.292
128.60	57	18.200	3.500	3.300	9.400	2.686	2.848
129.90	55	19.200	3.700	4.300	8.800	2.378	2.047
130.75	54	15.400	2.900	3.200	8.100	2.793	2.531
131.50	53	14.600	2.800	2.400	8.700	3.107	3.625
132.50	52	13.800	2.700	2.600	6.800	2.519	2.615
134.25	51	12.600	2.600	2.300	6.600	2.538	2.870
135.10	47	15.000	2.600	3.400	7.800	3.000	2.294
136.85	46	16.500	3.000	2.900	9.800	3.267	3.379
137.90	45	18.300	3.400	3.700	9.800	2.882	2.649
138.65	49	19.800	3.600	3.900	10.700	2.972	2.744
139.00	44	19.300	3.300	5.100	8.900	2.697	1.745
139.65	48	18.100	3.200	4.400	8.500	2.656	1.932
140.25	43	17.800	3.100	3.900	10.200	3.290	2.615
141.25	42	17.900	3.300	4.000	9.100	2.758	2.275
142.25	41	18.400	3.500	3.500	8.900	2.543	2.543
143.10	40	18.000	3.400	3.500	10.800	3.176	3.086
144.10	39	9.300	1.700	2.200	5.100	3.000	2.318

Figure A1.7 Tabulation of spectral gamma-ray data from Portugal

Above Base (m)	Station No	Peniche Gamma Data F					
		Total (ppmU)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
27.15	32	10.800	1.900	1.900	5.700	3.000	3.000
28.65	1	14.500	2.700	2.500	9.300	3.444	3.720
29.50	31	11.200	2.100	1.700	6.600	3.143	3.882
30.00	30	15.100	2.900	2.600	9.400	3.241	3.615
31.00	29	15.700	2.800	2.800	10.600	3.786	3.786
32.15	28	10.600	2.000	2.000	5.900	2.950	2.950
33.40	27	13.100	2.400	2.100	8.000	3.333	3.810
34.40	26	11.900	2.200	2.400	7.100	3.227	2.958
34.90	25	14.200	2.800	2.000	9.600	3.429	4.800
35.90	24	14.700	2.800	2.300	9.200	3.286	4.000
36.90	23	14.400	2.600	2.300	9.700	3.731	4.217
37.90	22	19.500	3.800	2.600	11.900	3.132	4.577
39.20	21	21.500	4.200	2.900	14.000	3.333	4.828
40.75	20	21.800	4.400	2.700	15.500	3.523	5.741
41.85	19	22.000	4.300	3.100	14.400	3.349	4.645
43.20	18	21.300	4.200	2.500	13.300	3.167	5.320
43.75	17	19.700	3.900	2.500	12.500	3.205	5.000
44.70	16	19.600	4.000	2.300	11.300	2.825	4.913
45.80	15	17.200	3.400	2.300	10.600	3.118	4.609
47.00	14	15.400	3.100	2.200	10.100	3.258	4.591
47.95	13	16.300	3.300	2.300	9.300	2.818	4.043
49.30	12	16.300	3.300	2.200	8.900	2.697	4.045
50.00	11	17.400	3.400	2.200	11.400	3.353	5.182
50.75	10	17.200	3.400	1.900	10.700	3.147	5.632
51.75	9	19.400	3.800	2.500	12.300	3.237	4.920
52.95	8	13.100	2.600	1.900	7.800	3.000	4.105
54.30	7	15.700	3.200	1.800	9.400	2.938	5.222
55.30	6	12.100	2.400	1.200	7.900	3.292	6.583
57.75	5	14.900	2.800	2.100	9.100	3.250	4.333
58.60	4	15.300	2.900	2.200	9.900	3.414	4.500
59.80	3	16.400	3.100	2.600	11.000	3.548	4.231
60.60	2	15.600	3.000	2.500	9.600	3.200	3.840

Figure A1.7 Tabulation of spectral gamma-ray data from Portugal (cont'd)

Wutach Beta Shale Data							
Station (m)	Total (ppm U)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U	
1 000	21 000	3 200	3 500	20 300	6 344	5 800	
1 250	21 000	3 200	4 200	17 300	5 406	4 119	
1 500	20 400	3 000	3 500	17 900	5 967	5 114	
1 750	20 500	3 100	3 300	19 000	6 129	5 758	
2 000	20 000	3 200	3 500	17 600	5 500	5 029	
2 250	19 800	3 000	3 600	17 500	5 833	4 861	
2 500	20 200	3 100	3 700	16 500	5 323	4 459	
2 750	19 900	3 000	3 100	18 600	6 200	6 000	
3 000	19 800	3 100	2 900	18 500	5 968	6 379	
3 250	19 700	3 000	3 400	18 600	6 200	5 471	
3 500	19 500	3 000	3 100	17 500	5 833	5 645	
3 750	19 200	2 900	4 000	15 900	5 483	3 975	
4 000	19 300	2 800	4 100	16 300	5 821	3 976	
4 250	18 800	2 900	2 900	16 800	5 793	5 793	
4 500	18 200	2 900	3 200	15 200	5 241	4 750	
4 750	19 300	3 000	3 500	16 200	5 400	4 629	
5 000	19 500	3 100	3 700	15 300	4 935	4 135	
5 250	19 200	3 000	3 400	14 000	4 667	4 118	
5 500	17 300	2 500	3 700	14 600	5 840	3 946	
5 750	18 800	2 900	3 500	15 400	5 310	4 400	
6 000	19 600	3 000	3 700	15 000	5 000	4 054	
6 250	19 500	3 000	3 800	15 000	5 000	3 947	
6 500	19 400	2 800	4 400	16 400	5 857	3 727	
6 750	19 900	2 700	4 400	16 100	5 963	3 659	
7 000	21 900	2 700	5 100	19 300	7 148	3 784	
7 450	14 100	1 700	3 900	12 200	7 176	3 128	
8 000	12 800	1 600	3 600	9 600	6 000	2 667	
8 450	10 800	1 500	3 400	8 100	5 400	2 382	
8 970	13 100	1 900	3 300	9 400	4 947	2 848	

Motorway Section Gamma							
Station	Above base	Total (ppm U)	K (%)	U (ppm)	Th (ppm)	Th/K	Th/U
1.000	0.000	8.900	1.300	2.700	6.000	4.615	2.222
2.000	1.200	10.500	1.700	2.300	7.100	4.176	3.087
3.000	2.000	11.200	1.700	3.000	7.700	4.529	2.567
4.000	2.600	10.400	1.600	3.100	6.500	4.062	2.097
5.000	3.200	10.500	1.600	2.800	7.100	4.438	2.536
6.000	4.200	11.000	1.700	3.000	7.600	4.471	2.533
7.000	5.500	11.600	1.800	2.800	9.200	5.111	3.286
8.000	6.400	10.900	1.500	3.800	7.300	4.867	1.921
9.000	7.200	13.100	1.900	3.200	10.400	5.474	3.250
10.000	7.700	12.800	1.900	3.900	8.400	4.421	2.154
11.000	8.200	14.000	2.100	3.400	10.300	4.905	3.029
12.000	8.900	12.700	1.900	3.900	8.300	4.368	2.128
13.000	9.400	15.400	2.300	4.500	9.800	4.261	2.178
14.000	9.800	13.300	2.100	3.300	9.400	4.476	2.848
15.000	10.800	15.800	2.600	3.200	11.800	4.538	3.688
16.000	11.800	17.200	2.700	3.800	12.400	4.593	3.263
17.000	12.800	16.400	2.700	3.800	12.600	4.667	3.316
18.000	14.000	18.400	2.700	4.300	13.500	5.000	3.140
19.000	15.000	17.100	2.800	3.200	13.300	4.750	4.156
20.000	16.000	19.300	3.100	4.000	15.400	4.968	3.850
21.000	17.000	18.400	3.000	2.800	14.500	4.833	5.179
22.000	18.000	18.200	3.000	3.200	15.200	5.067	4.750
23.000	19.000	19.200	3.000	3.400	16.300	5.433	4.794
24.000	20.300	18.300	2.800	4.000	15.800	5.643	3.950
25.000	21.400	19.500	3.000	4.200	16.200	5.400	3.857
26.000	22.400	18.700	2.800	4.200	15.000	5.357	3.571
27.000	23.500	19.000	2.900	4.200	14.500	5.000	3.452
28.000	24.500	16.900	2.400	4.700	13.000	5.417	2.766
29.000	25.400	16.600	2.400	4.900	13.000	5.417	2.653
30.000	26.300	14.600	1.900	4.600	10.200	5.368	2.217
31.000	27.000	15.300	2.300	4.000	11.600	5.043	2.900
32.000	28.100	15.000	2.200	4.500	9.700	4.409	2.156
33.000	28.800	15.500	2.500	3.200	11.900	4.760	3.719
34.000	29.600	16.900	2.600	4.100	13.200	5.077	3.220
35.000	30.400	17.800	3.000	3.400	13.200	4.400	3.882
36.000	32.100	17.600	2.300	6.200	10.400	4.522	1.677
37.000	32.800	10.300	1.100	4.800	6.700	6.091	1.396
38.000	33.200	12.600	1.700	4.500	7.900	4.647	1.756
39.000	33.600	12.400	1.500	4.800	7.500	5.000	1.563
40.000	34.000	12.700	1.700	4.600	8.300	4.882	1.804
41.000	35.000	11.400	1.600	4.600	6.600	4.125	1.435
42.000	36.000	13.300	1.500	6.200	6.900	4.600	1.113

Figure A1.8 Tabulation of spectral gamma-ray data from Germany

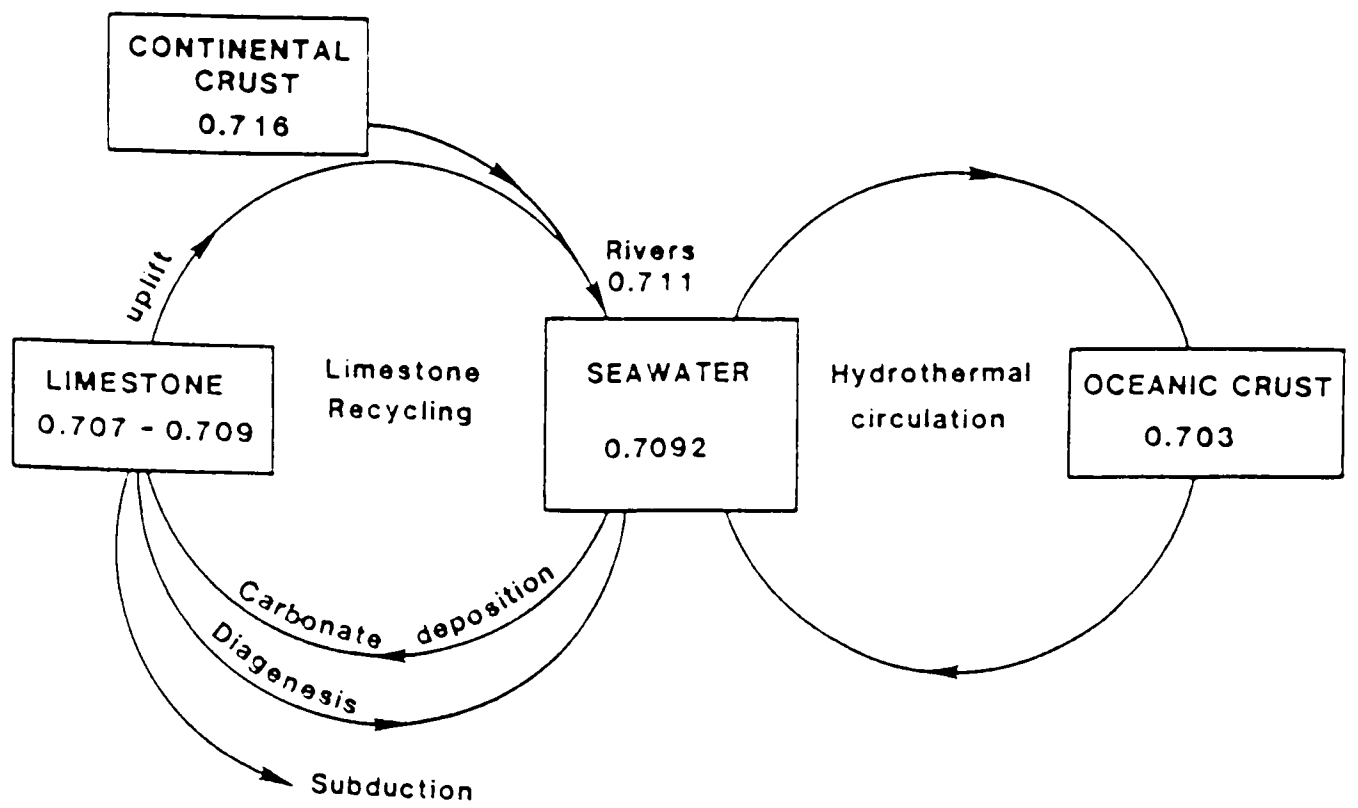


Figure A2.1a Box model for the marine geochemical cycle of strontium (from Elderfield, 1986)

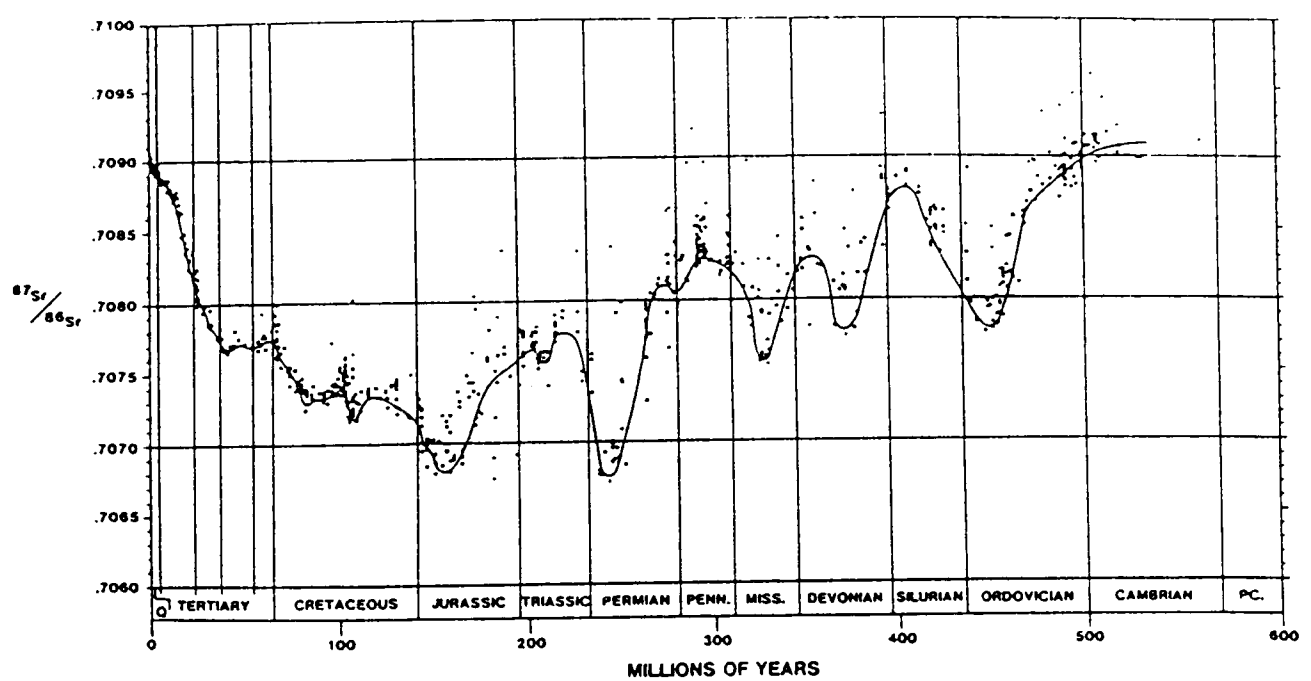


Figure A2.1b $^{87}\text{Sr}/^{86}\text{Sr}$ versus age for the Phanerozoic (from Burke et al., 1982)

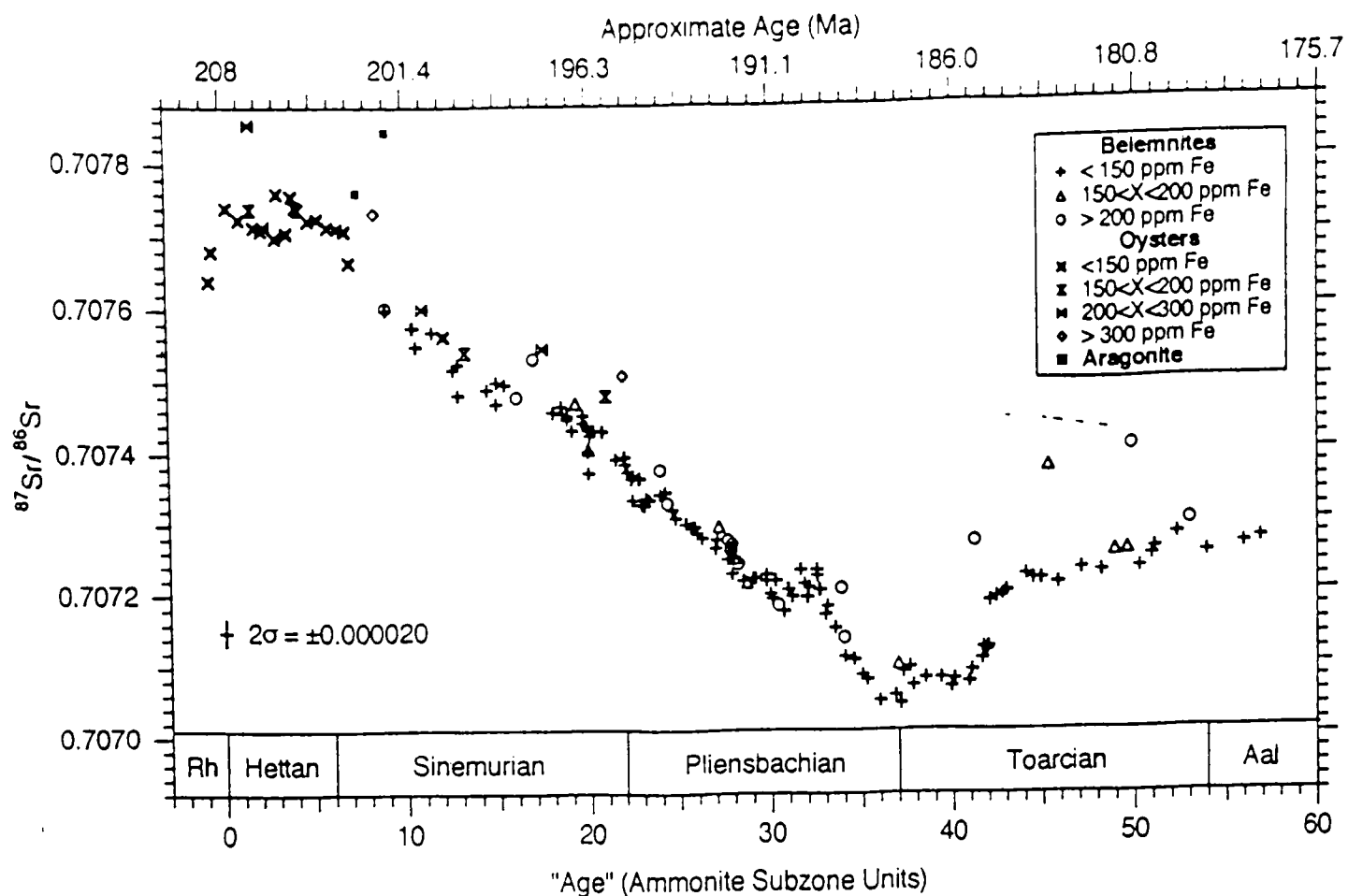
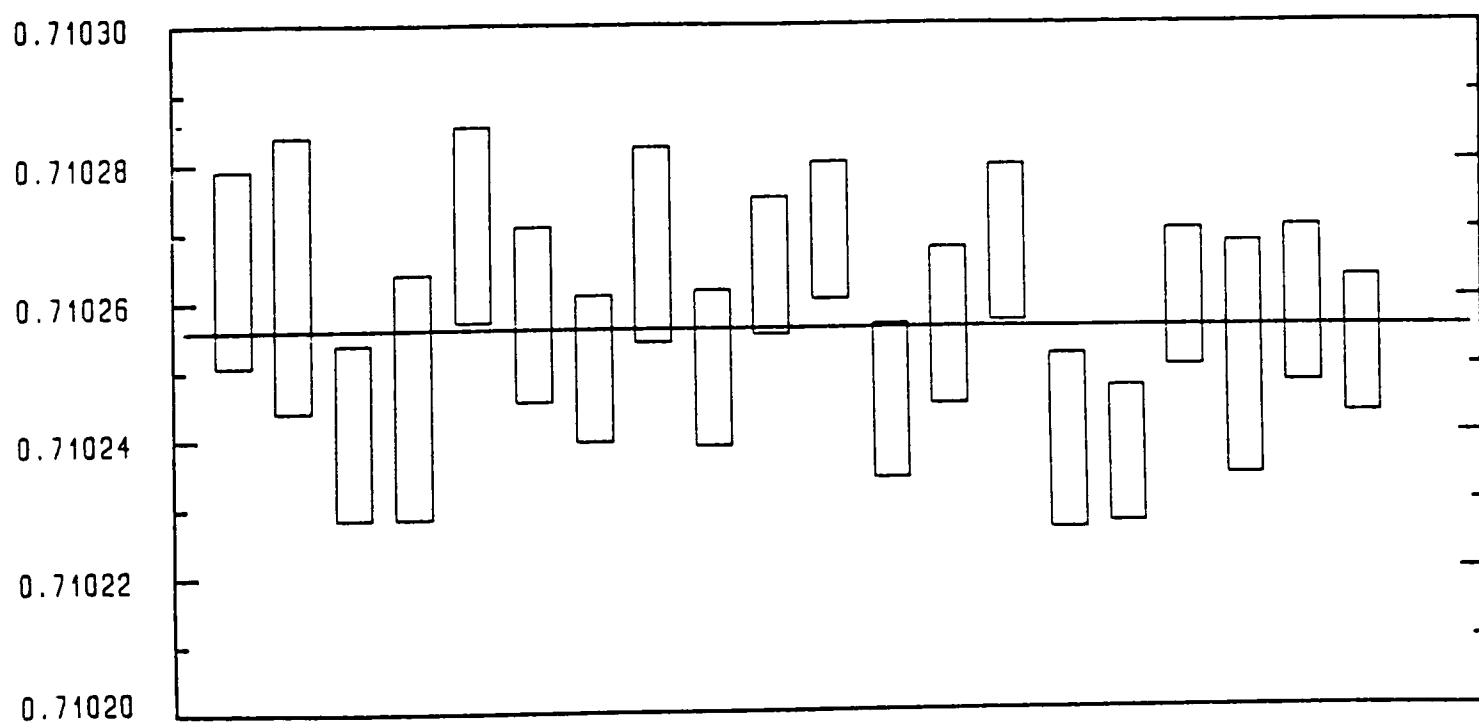


Figure A2.2a $^{87}\text{Sr}/^{86}\text{Sr}$ versus age for the Early Jurassic (from Jones, 1992)



WEIGHTED AVERAGE = $.710256 \pm .0000054$ (.00077%) 95% conf. limit
 external population error = .00002 (.0029%)
 M.S.W.D. = 3.23 Probability = 0

Figure A2.2b $^{87}\text{Sr}/^{86}\text{Sr}$ for twenty consecutive runs of NBS 987 on the Oxford VG Isomass 54E over the period of analysis for this thesis

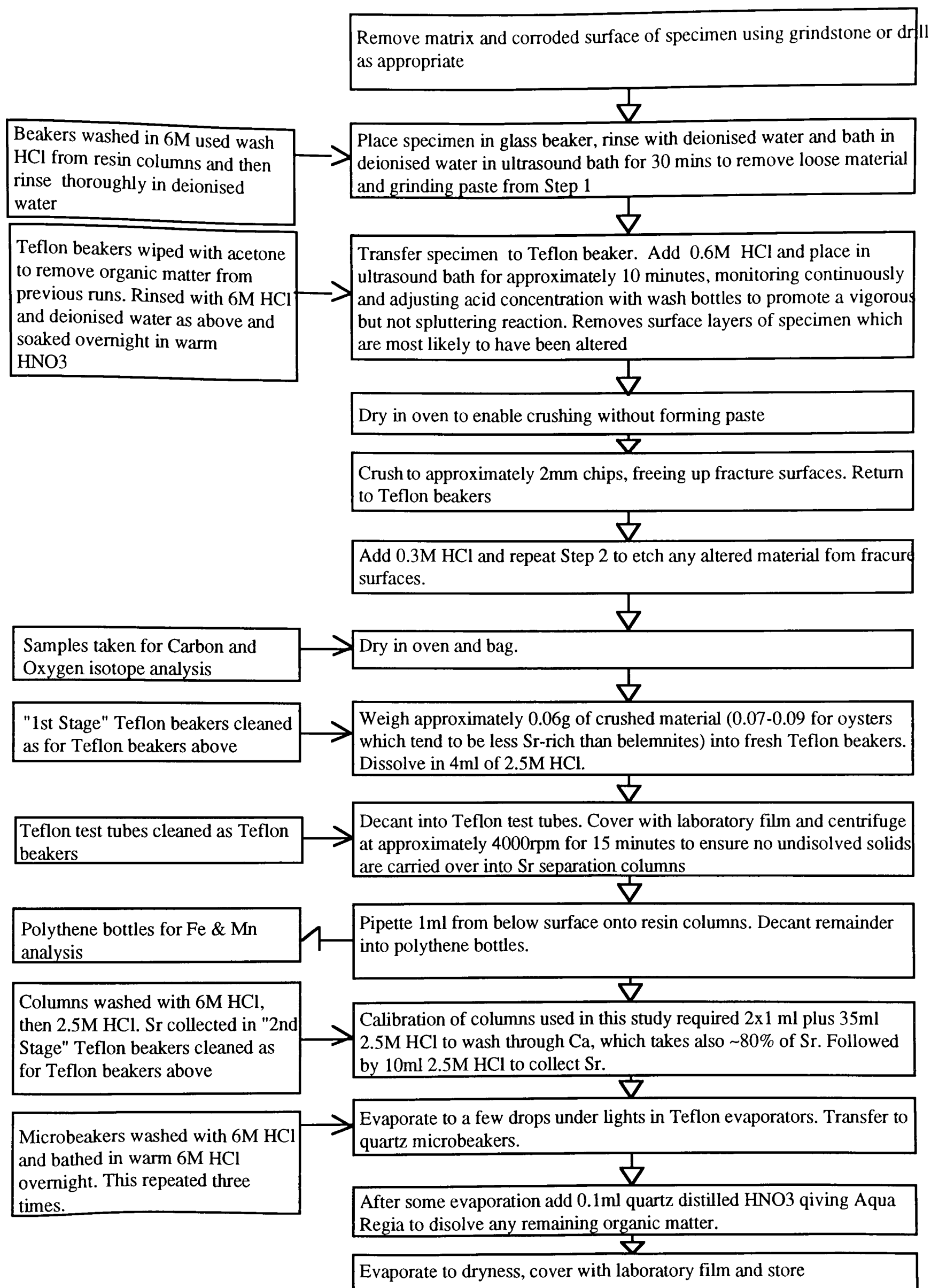


Figure A2.3 Flow chart for the Sr-isotopic analysis of skeletal material

Sample	m above base	Age (Ma)	δC13	δO18	Fe (ppm)	Mn (ppm)	Sr (low Mn)	Sr 87/86	Sr 87/86n	±2s	No. measures	Sample
P1	-0.170		-0.016	-1.000	22.02	7.61	0.707443	0.707449	0.707443	0.000023	239/240	P1
2PO4	0.0						0.707515	0.707521	0.707515	.000015		2PO4
P13	200.000	184.40	3.691	-0.656	80.09	12.92	0.707151	0.707157	0.707151	0.000027	153/165	P13
P29	0.000		3.256	-1.018	25.62	10.91	0.707476	0.707482	0.707476	0.000024	128/135	P29
P30	0.000		0.506	-0.830	33.32	10.22	0.707391	0.707397	0.707391	0.000013	193/195	P30
P51	69.370	194.68	-1.102	-1.724	29.42	10.51	0.707350	0.707356	0.707350	0.000017	238/240	P51
P53		194.62	-0.021	-1.824	24.36	9.86						P53
P56		194.57	-0.880	-1.073	33.28	8.76						P56
P59		194.55	-1.040	-0.759	56.05	8.15						P59
P62	73.950	194.47	-0.988	-0.619	64.19	4.99	0.707372	0.707378	0.707372	0.000026	87/90	P62
P63		194.32	-0.614	-0.814	51.56	9.58						P63
P64	77.750	194.31	-1.046	-0.772	100.83	12.46	0.707383	0.707389	0.707383	0.000013	187/195	P64
P64 (*)	77.750	194.31	-1.046	-0.772	-	-	0.707384	0.707390	0.707384	0.000022	98/105	P64 (*)
P66	78.290	194.29	0.518	-1.173	79.45	9.00	0.707353	0.707359	0.707353	0.000014	174/180	P66
P70	78.750	194.26	-0.632	-0.983	80.14	11.19	0.707362	0.707368	0.707362	0.000011	187/195	P70
P75a		194.22	-0.846	-0.997								P75a
P75b	81.110	194.17	0.447	-0.614	31.6	7.75	0.707346	0.707352	0.707346	0.000015	187/195	P75b
P79		194.13	-0.358	-0.884								P79
P82		194.08	-0.841	-1.242								P82
P85	85.880	193.75	0.085	-2.381	62.83	7.73	0.707333	0.707339	0.707333	0.000014	189/195	P85
P88		193.94	0.168	-1.387	247.01	31.37	0.707342	0.707348	0.707342	0.000014	205/225	P88
P89	87.120	193.93	0.150	-1.037	48.82	6.09	0.707313	0.707319	0.707313	0.000011	187/195	P89
P95		193.85	-0.336	-1.218	91.91	15.11	0.707320	0.707326	0.707320	0.000013	193/210	P95
P97	90.610	193.77	0.484	-1.312	72.66	17.25	0.707324	0.707330	0.707324	0.000032	128/135	P97
P98		193.74	-1.407	-2.231	1563.77	44.16						P98
P100	93.120	193.60	-1.588	-1.016	233.23	10.38		0.707288	0.707282	0.000015	170/180	P100
P100 (*)		193.60			-	-	0.707316	0.707322	0.707316	0.000018	210/220	P100 (*)
P105		193.43	0.067	-1.33	58.6	9.53	0.707322	0.707328	0.707322	0.000018	141/150	P105
P108		193.24	0.788	-1.465	76.95	14.88	0.707310	0.707316	0.707310	0.000011	186/195	P108
P109	96.620	193.22	0.366	-1.015	32.7	6.66		0.707255	0.707249	0.000021	200/210	P109
P109(*)	96.62	193.22			-	-	0.707313	0.707319	0.707313	0.000026	139/150	P109(*)
P110		193.15	-0.040	-1.876	74.61	13.39						P110
P112		193.05	0.286	-1.616	54.03	10.63						P112
P113		193.10	0.033	-1.592	621.89	44.68	0.707314	0.707320	0.707314	0.000015	199/210	P113
P114		192.70	0.035	-1.492	11.24	12.72	0.707299	0.707305	0.707299	0.000013	189/195	P114
P116	99.450	192.47	1.422	-1.202	98.73	15.12	0.707261	0.707267	0.707261	0.000013	190/195	P116
P117	102.710	192.45	0.863	-1.269	60.32	10.38	0.707283	0.707289	0.707283	0.000015	202/210	P117
P118	106.730	192.20	1.522	-1.295	58.27	11.95	0.707259	0.707265	0.707259	0.000014	190/195	P118
P119		190.20	0.193	-2.374	179.1	19.45	0.707235	0.707241	0.707235	0.000011	160/165	P119
P123	117.760	190.10	1.061	-2.249	47.48	4.41	0.707209	0.707215	0.707209	0.000015	232/240	P123
P125		190.05	0.110	-2.402	110.22	8.76	0.707274	0.707280	0.707274	0.000015	216/225	P125
P127	120.040	189.94	0.356	-2.522	91.79	11.23						P127
P129		189.75	0.346	-1.736	84.42	11.7	0.707217	0.707223	0.707217	0.000015	178/180	P129
P134	124.490	189.67	1.919	-1.064	111.56	12.58	0.707207	0.707213	0.707207	0.000021	174/180	P134
P135		189.63	0.854	-1.336	52.14	9.71						P135
P136		189.58	1.706	-1.113	142.44	15.99						P136
P138		189.47	1.000	-1.154	136.84	17.54						P138

Figure A2.4 Tabulation of ⁸⁷Sr/⁸⁶Sr data for belemnites from the Lower Jurassic of Peniche, Portugal

Sample	m above base	Age (Ma)	δC13	δO18	Fe (ppm)	Mn (ppm)	Sr (low Mn)	Sr 87/86	Sr 87/86n	±2s	No. measures	Sample
P139		189.51	1.795	-0.694	35.84	7.17	0.707158	0.707164	0.707158	0.000016	179/195	P139
P141	128.360	189.40	0.873	-0.990	34.83	4.64						P141
P143		189.32	1.045	0.995	73.51	11.94						P143
P146		189.24	2.311	-0.642	53.27	7.81						P146
P151	132.650	189.15	1.371	-1.349	33.09	7.35	0.707136	0.707142	0.707136	0.000020	153/160	P151
P153		189.05	0.931	-1.001								P153
P155	135.010	189.00	-0.199	-1.208	80.34	9.36	0.707142	0.707148	0.707142	0.000015	203/210	P155
P163		188.95	0.674	-1.11								P163
P165		188.94	1.255	-0.629								P165
P167	136.370	188.93	1.136	-0.141	34.03	6.92	0.707160	0.707166	0.707160	0.000014	183/195	P167
P168a	136.480	188.92	2.006	-0.592	49.11	6.56	0.707166	0.707172	0.707166	0.000020	200/210	P168a
P168b		188.92	1.398	-0.426								P168b
P169	136.780	188.90	2.017	-0.197	63.9	9.99	0.707135	0.707141	0.707135	0.000014	181/195	P169
P170		188.89	1.425	-0.345								P170
P178	140.140	188.50	0.926	-0.332	37.95	6.72	0.707121	0.707127	0.707121	0.000013	186/195	P178
P183		188.60	1.226	-0.4235								P183
P186	143.680	188.70	2.284	-0.197	37.51	5.97	0.707168	0.707174	0.707168	0.000011	189/195	P186
P188		188.80	1.734	-0.15								P188
P193	146.490	188.40	0.984	-0.341	34.1	4.84	0.707140	0.707146	0.707140	0.000020	192/195	P193
P196		188.20	1.370	-0.188								P196
P200	150.060	188.12	1.206	-0.608	46.69	4.34	0.707096	0.707102	0.707096	0.000020	131/135	P200
P200 (*)	150.060	188.12	1.206	-0.608	37.78	4.57	0.707121	0.707127	0.707121	0.000013	187/196	P200 (*)
P207		188.03	1.579	0.121								P207
P208	154.130	187.93	2.630	0.315	49.63	6.29	0.707094	0.707100	0.707094	0.000011	191/195	P208
P211		187.83	1.035	-0.408								P211
P215	158.440	187.70	0.473	-0.408	29.41	5.75	0.707091	0.707097	0.707091	0.000013	187/195	P215
P216	163.590	187.45	2.335	-0.221	33.95	4.33	0.707073	0.707079	0.707073	0.000024	222/225	P216
P220	163.960	187.40	1.802	-0.258	92.52	13.12	0.707060	0.707066	0.707060	0.000018	145/150	P220
P221		187.25	1.397	-0.519								P221
P222		187.15	2.479	-0.786								P222
P223	163.250	187.55	0.741	-0.186	78.54	9.31	0.707068	0.707074	0.707068	0.000011	192/195	P223
P224		186.95	1.638	-0.720								P224
P227	167.560	186.80	1.914	-0.788	26.86	4.99	0.707096	0.707102	0.707096	0.000016	186/195	P227
P230		186.65	2.461	-0.546								P230
P232		186.50	2.642	-0.436								P232
P233		186.35	2.738	-0.594								P233
P234	171.420	186.20	4.391	-0.680								P234
P244	53.900	195.40			24.46	6.56	0.707427	0.707433	0.707427	0.000011	185/195	P244
P244 (*)	53.900	195.40			-	-	0.707399	0.707405	0.707399	0.000014	221/225	P244 (*)
P245	57.190	195.30	-0.526	-2.538								P245
P298		187.60	1.030	-0.366								P298
P309	177.420	185.50	0.271	-3.162	6236.67	617.83	0.707299	0.707299	0.707293	0.000014	146/150	P309

Figure A2.4 Tabulation of ⁸⁷Sr/⁸⁶Sr data for belemnites from the Lower Jurassic of Peniche, Portugal (cont'd)

Sample	%Matrix above	Age (Ma)	δ13C	δ18O	Fe (ppm)	Mn (ppm)	Sr 87/86	Sr 87/86n	±2s	No. measures	sample
GMB 1	0.650	195.300	1.390	-0.950	144.82	33.72	0.707372	0.707366	0.000015	233/240	GMB 1
GMB 2	1.050	195.000	0.420	-1.009	87.67	27.94	0.707377	0.707371	0.000022	202/210	GMB 2
GMB 3	1.500	194.800	0.990	-0.740	955.48	11.94	0.707382	0.707376	0.000016	190/195	GMB 3
GMB 4	2.270	194.300	0.386	-0.388	101.60	26.88	0.707360	0.707354	0.000015	168/180	GMB 4
GMB 5	3.320	193.800	-0.134	-0.827	41.27	22.01	0.707343	0.707337	0.000013	159/165	GMB 5
GMB 6	3.150	193.900	1.150	-0.097	92.56	32.95	0.707349	0.707341	0.000015	212/220	GMB 6
GMB 7	3.800	193.500	0.920	0.010	50.19	18.47	0.707331	0.707325	0.000014	187/195	GMB 7
GMB 8	4.630	193.100	0.845	-1.191	1834.48	345.22					GMB 8
GMB 9	6.600	191.900	1.830	0.030	67.82	19.21	0.707282	0.707276	0.000011	186/195	GMB 9
GMB 10	6.600	191.900	0.997	-0.098	70.26	25.78	0.707235	0.707229	0.000035	115/120	GMB 10
GMB 11	7.070	191.700	2.500	-0.780	95.64	28.86	0.707263	0.707257	0.000010	183/195	GMB 11
GMB 12	7.550	190.500	2.500	-1.520	94.16	44.67	0.707236	0.707230	0.000030	128/135	GMB 12
GMB 13	7.900	190.400	2.150	-3.620	213.14	84.63	0.707278	0.707272	0.000028	100/105	GMB 13
GMB 14	8.800	190.100	1.770	-0.530	81.19	20.16	0.707217	0.707211	0.000020	199/210	GMB 14
GMB 15	9.500	189.900	0.990	-0.890	77.34	29.97	0.707215	0.707209	0.000014	176/180	GMB 15
GMB 16	9.850	189.800	1.050	-0.570	92.17	16.99	0.707267	0.707261	0.000013	189/190	GMB 16
GMB 17	11.450	189.570	1.000	-0.520	28.62	34.72	0.707200	0.707194	0.000014	186/195	GMB 17
GMB 18	12.820	189.440	2.011	-0.855	93.99	43.58	0.707209	0.707203	0.000017	202/210	GMB 18
GMB 19	13.650	189.370	2.940	-0.150	92.54	37.01	0.707192	0.707186	0.000014	184/195	GMB 19
GMB 20	15.700	189.230	2.010	-0.090	32.41	54.02	0.707175	0.707169	0.000021	184/196	GMB 20
GMB 21	16.400	189.180	2.480	-0.280	130.69	38.30	0.707184	0.707178	0.000015	218/225	GMB 21
GMB 22	20.500	188.940	2.120	0.300	30.54	69.57	0.707210	0.707204	0.000015	200/210	GMB 22
GMB 23	21.350	188.870	1.622	-0.011	130.69	38.30	0.707186	0.707180	0.000020	172/180	GMB 23
GMB 24	22.850	188.780	1.490	-0.050	73.70	22.96	0.707127	0.707121	0.000015	224/240	GMB 24
GMB 25	23.600	188.710	1.609	0.074	108.77	43.86	0.707129	0.707123	0.000017	131/135	GMB 25
GMB 26	25.450	188.640	0.440	-0.180	65.88	23.99					GMB 26
GMB 27	25.800	188.500	1.478	-0.561	179.18	70.85	0.707097	0.707091	0.000011	189/195	GMB 27
GMB 28	27.150	188.100	1.900	0.110	27.93	11.97	0.707084	0.707078	0.000015	186/195	GMB 28
GMB 29	27.550	187.900	1.320	-0.410	65.92	25.35					GMB 29
GMB 30	28.900	187.400	1.120	-0.510	81.28	40.20	0.707085	0.707079	0.000013	164/165	GMB 30
GMB 31	30.400	186.900	2.610	-0.620	1035.26	36.23	0.707054	0.707048	0.000036	84/90	GMB 31

Figure A2.5. Tabulation of ⁸⁷Sr/⁸⁶Sr data for belemnites from the Lower Jurassic of the B27 Roadcut, South Germany

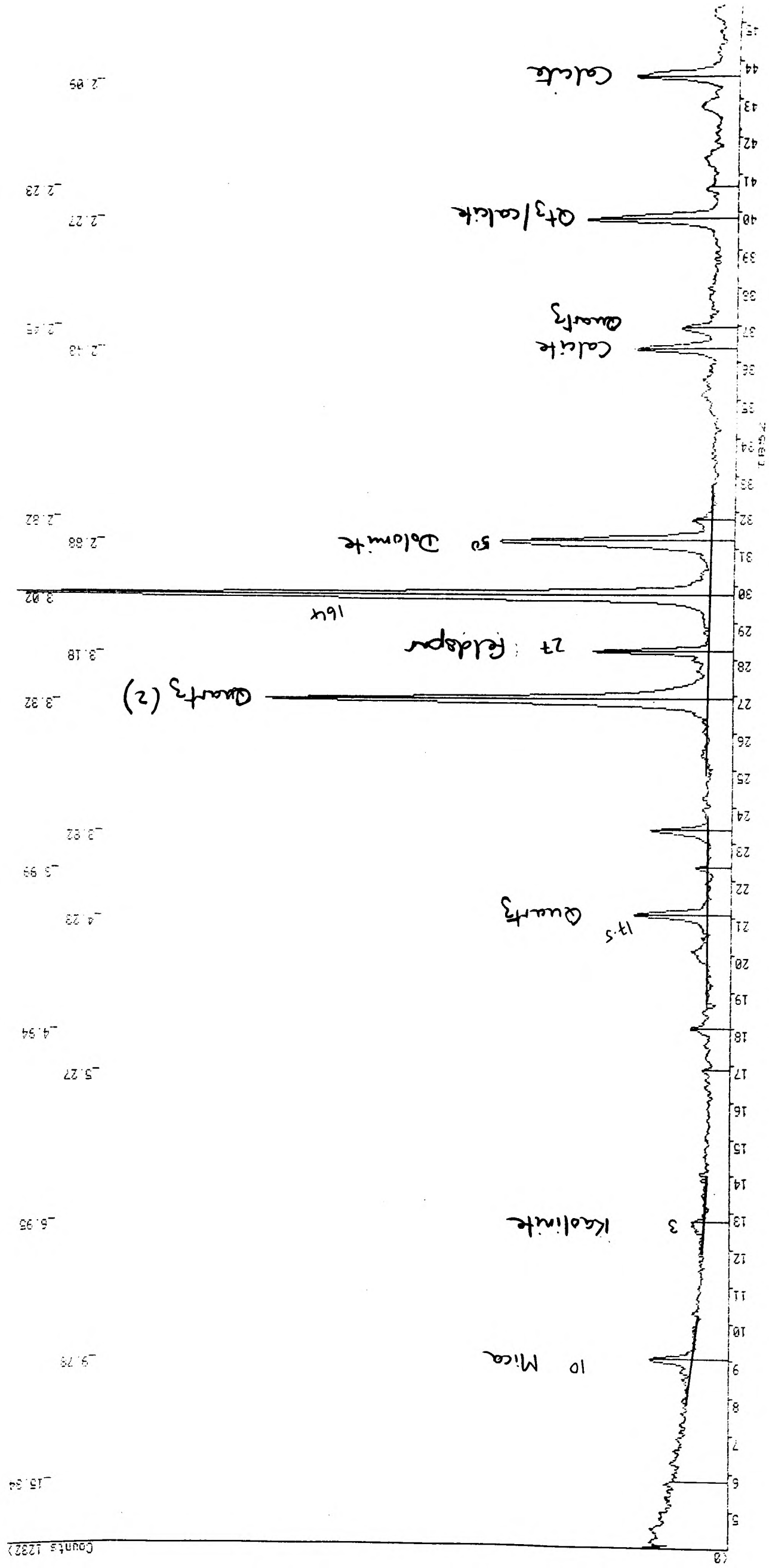


Figure A3.1 Typical diffractogram from the Pliensbachian of the Breggia Gorge section (sample IB52). Peaks labeled in Angstroms, base scale in degrees two-theta. Principal peaks identified.

'H' Factors for the PW1710

Angle	d-space(Å)	Mineral	Factor	Notes
5	17.00	Montmorillonite	1.1997	
6.3	14	Chlorite	0.3106	Possible smectite overlap
6.3	13.92	Mordenite	7.85	
8.5	10.10	Glaucanite	5.26	
8.80	10	Mica	0.4695	
9.60	9.21	Mordenite	4.40	
10.40	8.5	Amphibole	0.12	Calculated from I/I ^C for Hornblende
11.62	7.62	Gypsum	1.0782	
12	7.33	Serpentine	0.90	Calculated from I/I _C for Amesite.
12.5	7	Kaolinite	0.9404	
14.7	6.02	Bassanite	1.3012	Gypsum hemi-hydrate
17.77	4.98	Goethite	6.1419	25% peak to avoid overlaps
18.27	4.85	Gibbsite	0.9617	
19.36	4.58	Glaucanite	4.06	
20.30	4.37	Gibbsite	2.5010	
20.80	4.26	Quartz	1.0	Preferred Quartz
22.10	4.02	Mordenite	2.75	
24.30	3.66	Haematite	1.8921	
24.8	3.58	Siderite	1.1797	
	3.55	Chlorite		
	3.53	Kaolinite		
25.5	3.49	Anhydrite	0.053	
25.5	3.49	Mordenite	2.82	Possible Anhydrite overlap
27.03	3.29	Zircon	0.1313	
27.16	3.28	Aragonite	5.9722	
27.4	3.25	Microcline	0.32	Quartz at 4.26Å may be enhanced
27.94	3.19	Albite	0.3199	
	3.15	Sylvite	0.166	
28.4	3.13	Sphalerite	0.23	Calculated from I/I _C .
28.8	3.09	Baryte	0.5804	
28.8	3.09	Mordenite	3.66	
29.43	3.03	Calcite	0.264	
29.75	3.00	Bassanite	0.9740	
30.80	2.90	Ankerite	0.33	Only usable peak
30.37	2.94	Amphibole	0.09	Calculated from I/I ^C for Hornblende
30.94	2.88	Dolomite	0.356	
31.6	2.82	Fayalite	4.2170	
31.6	2.82	Halite	0.1824	Main peak.
31.82	2.81	Apatite	0.5455	
31.93	2.80	Bassanite	1.4776	
32.04	2.79	Siderite	0.2334	Possible feldspar overlap
33.02	2.71	Pyrite	0.6669	
33.14	2.70	Aragonite	3.0239	Iron mineral overlap
33.15	2.70	Haematite	0.4625	
33.15	2.70	Amphibole	0.06	Calculated from I/I ^C for Hornblende
34.20	2.62	Apatite	2.1750	
34.60	2.59	Glaucanite	3.57	
35.42	2.53	Magnetite	0.8810	
35.89	2.50	Olivine	3.2459	Fosterite >30%
35.89	2.50	Fayalite	3.2459	
36.64	2.45	Quartz	2.4835	
37.44	2.40	Glaucanite	6.87	
37.76	2.38	Gibbsite	4.8661	
37.92	2.37	Aragonite	4.1910	
41.98	2.15	Wustite	1.9610	Quartz at 41.98 = 0.05482 × Intensity of quartz at 4.26A
45.43	1.99	Halite	0.8084	
46.78	1.94	Apatite	2.08	
50.37	1.81	Quartz	1.6648	
56.40	1.63	Pyrite	0.7675	
56.45	1.62	Halite	3.7551	
57.95	1.59	Haematite	3.0720	
60.02	1.54	Quartz	2.260	
61.34	1.51	Glaucanite	6.56	
62.52	1.48	Magnetite	2.7356	

Figure A3.2 Semi-quantitative ("H") factors for the Reading University PW1710 diffractometer

Metres	Calcite (%)	Dolomite (%)	Quartz (%)	Feldspar (%)	Mica (%)	Kaolinite (%)
0.000	50.890	18.570	29.480	0.000	1.060	0.000
1.000	48.900	22.370	17.640	10.050	1.040	0.000
2.000	60.310	11.860	27.190	0.000	0.640	0.000
3.000	66.640	10.130	23.220	0.000	0.000	0.000
4.000	66.420	2.130	31.450	0.000	0.000	0.000
4.000	66.680	2.120	31.200	0.000	0.000	0.000
5.000	54.910	17.740	26.160	1.200	0.000	0.000
6.000	68.870	9.400	21.740	0.000	0.000	0.000
7.000	55.750	14.450	29.800	0.000	0.000	0.000
8.200	68.940	7.750	23.320	0.000	0.000	0.000
9.000	45.600	26.300	28.100	0.000	0.000	0.000
10.000	62.100	17.730	17.990	0.890	1.300	0.000
11.000	72.260	7.830	16.290	2.090	1.530	0.000
12.000	69.570	7.170	23.250	0.000	0.000	0.000
13.000	83.490	8.040	8.470	0.000	0.000	0.000
14.000	88.340	1.760	9.900	0.000	0.000	0.000
15.000	64.210	13.480	19.660	0.930	1.710	0.000
16.000	84.970	2.710	11.430	0.000	0.890	0.000
17.000	72.770	0.000	23.320	0.000	3.910	0.000
18.000	65.730	12.130	20.750	0.000	1.390	0.000
19.000	64.210	12.370	21.720	0.000	1.700	0.000
20.000	80.970	2.600	16.430	0.000	0.000	0.000
21.000	62.110	9.850	26.290	0.440	1.300	0.000
22.000	60.050	15.480	21.410	0.860	2.200	0.000
23.000	65.080	2.090	29.350	1.410	0.690	1.380
24.000	74.930	3.290	20.990	0.000	0.790	0.000
25.000	69.930	1.120	28.210	0.000	0.740	0.000
26.000	76.180	6.040	16.980	0.000	0.800	0.000
27.000	76.880	6.100	15.420	0.000	1.610	0.000
28.000	77.740	4.930	17.320	0.000	0.000	0.000
29.000	65.670	7.380	23.690	0.470	2.780	0.000
30.000	70.400	1.130	26.980	0.000	1.490	0.000
31.000	88.120	0.000	11.880	0.000	0.000	0.000
32.000	81.690	0.000	16.580	0.000	1.730	0.000
33.000	74.100	0.000	23.530	0.000	2.370	0.000
37.000	77.230	0.000	22.770	0.000	0.000	0.000
38.000	69.150	4.440	24.950	0.000	1.460	0.000
39.000	78.840	0.940	18.550	0.000	1.660	0.000
40.000	62.500	4.510	31.000	0.000	1.980	0.000
41.000	66.110	5.910	23.380	0.000	4.600	0.000
42.000	68.510	7.110	21.500	0.000	2.880	0.000
43.000	85.190	0.000	14.360	0.000	0.450	0.000
44.000	64.930	13.470	17.460	1.400	2.730	0.000
45.000	83.140	4.670	12.190	0.000	0.000	0.000
46.000	82.560	2.640	14.800	0.000	0.000	0.000
47.000	70.410	9.830	15.780	1.010	1.480	1.480
48.000	64.260	7.690	27.370	0.000	0.680	0.000
49.000	68.370	7.730	21.710	0.000	2.180	0.000
50.000	60.420	10.240	27.410	0.000	1.930	0.000
51.000	60.000	16.760	18.830	0.000	4.420	0.000
52.000	45.690	18.790	18.470	9.120	4.960	2.980
53.000	52.150	17.790	23.510	0.750	3.590	2.210
54.000	83.910	3.990	11.220	0.000	0.880	0.000
55.000	71.230	14.170	12.730	0.000	1.870	0.000
56.000	70.540	7.120	16.800	1.020	3.000	1.500
57.000	82.590	4.590	11.960	0.000	0.860	0.000
58.000	83.910	3.990	11.220	0.000	0.880	0.000
59.000	75.860	5.450	16.150	0.540	2.000	0.000
60.000	78.420	0.000	17.470	0.000	4.100	0.000
61.000	78.040	0.000	19.470	0.000	2.490	0.000
62.000	81.870	0.000	16.420	0.000	1.710	0.000
63.000	81.680	1.960	14.650	0.000	1.720	0.000
64.000	74.070	7.090	16.600	1.060	1.170	0.000
65.000	79.650	0.000	16.960	1.710	1.680	0.000
66.000	59.290	0.000	38.380	0.000	2.340	0.000
67.000	86.330	0.000	11.680	0.620	1.370	0.000
68.000	90.790	0.000	7.120	0.650	1.430	0.000
68.800	95.660	0.000	4.340	0.000	0.000	0.000
70.000	87.780	0.000	8.830	0.630	2.760	0.000
71.000	90.010	0.000	8.090	0.000	1.900	0.000
71.200	93.760	0.000	5.250	0.000	0.990	0.000
71.700	80.880	0.000	15.410	1.160	2.550	0.000
72.000	86.270	1.380	7.780	0.000	4.570	0.000
72.500	87.530	0.000	7.940	1.270	3.260	0.000
73.000	76.270	0.000	18.860	1.650	3.220	0.000
73.500	75.050	0.000	17.230	1.650	3.640	2.430
74.000	67.550	0.000	21.390	2.440	4.300	4.310
74.500	72.850	0.000	17.140	1.570	5.370	3.070
75.000	65.460	0.000	27.550	1.960	2.160	2.880
75.500	71.810	0.000	17.470	2.130	3.910	4.690
76.000	79.150	0.000	18.280	0.000	2.570	0.000
76.100	80.600	0.000	16.400	0.000	3.000	0.000
76.500	74.660	0.000	17.240	0.000	4.050	4.050
77.000	77.520	0.000	14.810	1.120	2.450	4.100
77.500	73.430	0.000	20.540	0.000	2.810	3.220
78.000	74.880	0.000	20.320	1.630	3.180	0.000
78.500	83.740	0.000	11.230	2.400	2.640	0.000

Figure A3.3 Tabulation of mineral percentages based on relative peak heights from diffractograms

0.00	196.280	1.804	-1.699
1.00	196.150	1.849	-1.110
8.20	195.200	1.785	-1.000
2.00	196.020	1.865	-1.541
3.00	195.890	1.659	-2.005
4.00	195.760	1.347	-2.126
5.00	195.630	1.665	-1.530
6.00	195.500	1.652	-1.504
7.00	195.370	1.786	-1.482
8.00	195.240	1.248	-3.387
1.00		1.792	-1.052
9.00	195.110	1.921	-0.859
11.00	194.850	2.000	-1.359
12.00	194.720	2.129	-1.037
13.00	194.590	1.953	-1.067
14.00	194.460	1.838	-0.835
16.00	194.200	1.717	-1.246
17.00	194.070	1.257	-2.185
18.00	193.940	1.896	-1.055
19.00	193.810	1.282	-2.870
1.00		1.763	-1.266
20.00	193.680	1.781	-1.641
21.00	193.550	1.830	-1.966
22.00	193.420	1.849	-1.305
23.00	193.290	1.972	-1.670
24.00	193.160	1.902	-1.629
26.00	192.900	1.941	-1.003
27.00	192.770	1.973	-1.719
28.00	192.640	1.878	-1.021
29.00	192.510	1.846	-1.918
1.00		1.830	-1.180
30.00	192.380	1.611	-2.058
33.00	191.990	1.335	-2.062
42.00	190.820	1.765	-1.299
44.00	190.560	1.934	-1.422
47.00	190.170	1.968	-1.193
1.00		1.835	-1.225
10.00		1.897	-1.617
25.00		1.714	-0.850
32.00		1.533	-2.121
41.00	190.950	1.939	-1.075
43.00	190.690	1.834	-1.652
46.00	190.300	1.921	-1.030
49.00	190.030	1.853	-1.052
50.00	189.990	1.902	-1.235
51.00	189.960	1.787	-1.323
52.00	189.920	1.970	-0.571
1.00		1.755	-0.849
53.00	189.880	1.974	-0.920
55.00	189.810	1.968	-1.427
56.00	189.770	1.979	-1.103
59.00	189.650	2.064	-1.038
61.00	189.530	1.928	-1.668
64.00	189.210	2.398	-1.280
65.00	189.100	2.329	-1.354
6.00		2.226	-2.963
67.00	188.770	2.408	-1.465
1.00		1.874	-1.123
68.00	188.600	2.370	-1.679
68.80	188.420	2.511	-1.762
70.00	188.160	2.628	-1.567
71.70	187.820	1.500	-2.624
71.20	187.920	2.713	-1.368
73.00	187.600	2.839	-2.226
73.50	187.550	2.884	-1.843
74.00	185.500	2.424	-2.053
74.50	185.270	2.235	-2.255
75.00	185.050	2.540	-1.855
76.00	184.650	2.670	-1.803
78.00	183.750	2.676	-1.665
78.50	183.525	2.721	-1.877
1.00		1.819	-1.241
54.00		1.884	-1.512
57.00		1.957	-1.427
58.00		1.967	-2.182
60.00		1.944	-1.342
62.00		1.974	-1.435
63.00		2.315	-1.869
1.00		1.534	-1.472
66.00		2.082	-3.061
71.00		0.905	-2.774
72.00		2.220	-2.405
72.50		2.874	-2.545
75.50		2.429	-2.005
76.10		2.814	-1.738
76.50		2.285	-2.254
77.50		2.585	-1.775

Figure A3.4 Tabulation of stable isotope data from the Breggia Gorge section

