GEOLOGY OF CENTRAL RAASAY.

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GEOLOGY

OF

CENTRAL RAASAY

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ABSTRACT

A $16km^2$ area in central Raasay was mapped during the summer of 1988. The Precambrian (Lewisian and Torridonian), Jurassic and Quaternary are present together with the enigmatic Brecciated Torridonian.

The Lewisian is exposed in the north and is represented by hornblende-biotite gneisses and amphibolitized Scourie dykes. After the intrusion of the dykes the area was affected by the Laxfordian Event. This produced two phases of metamorphism, four phases of folding and a major phase of pegmatite injection. The Grenville Event may be represented by N-S fault zones.

The Torridonian overlies the Lewisian unconformably usually with basal conglomerates (Basal Facies). It is represented by a thin siltstone sequence (lacustrine) overlain by extensive red braided stream sandstones. Soft sediment deformation is widespread and indicates synsedimentary tectonic activity.

The Jurassic is separated from the Torridonian by faulting. It consists of a lower marine sequence (Broadford Beds, Scalpa Sandstone, Portree Shales, Raasay Ironstone and Bearreraig Sandstone) followed by a fresh or brackish water sequence (Great Estuarine Group). The most important discoveries were in situ deposits of the Duntulm Formation (Great Estuarine Group) and a striatulum subzone fauna in the Raasay Ironstone.

The "vents" recorded by the BGS are herein named the Brecciated Torridonian and considered to be some form of collapse structure.

The Quaternary Glaciation is indicated by boulder clay, erratics and striae.

During the Tertiary dolerite sills and dykes(NNW-SSE) and a granophyre sill were intruded into the sediments.

A gentle, E-W, ?Caledonian anticline and reverse faults are present in the Torridonian.

During the late Tertiary the area was tilted towards the west with the formation of N-S normal faults and possibly the major E-W Holoman Screapadal Fault.

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1. INTRODUCTION

The Isle of Raasay lies in the Inner Hebrides between the Isle of Skye and the Scottish Mainland. It is a small island, 20km long with a population of about 200 who live mainly in the south. It was chosen for study because it has a good representation of the geology of the Hebridean Region and to determine the affinity of its belemnite faunas.

A 16km^2 area in central Raasay was surveyed during a six week period in the summer of 1988. Although the weather was poor the geology of the area was covered in reasonable detail.

The topography of the area is dominated by a series of westward dipping ledges formed by bedding planes in the Torridonian and sills intruded into the Jurassic. On the east coast there are spectacular cliffs about 400m high which cannot be mapped in detail because of their inaccessibility. In the north the Lewisian forms a series of ragged low hills.

The vegetation consists mainly of grassy moorland with numerous small peat bogs. Heather is fairly common and grows mainly on the peat. There is one small Forestry Commission coniferous plantation.

This report concentrates on the general geology of the area but with particular emphasis on new finds. Much of the detail has had to be omitted because of lack of space.

GRID REFERENCES. 6 figure grid references are given in brackets after locations. The grid letters NG have been omitted from all grid references because the survey area is small.

ACKNOWLEDGMENTS. I am grateful to the following; Miss R. Elliott for showing me locations in southern Raasay and for presenting me with belemnite material; Mr and Mrs Gillies who made my stay in Raasay very enjoyable.

2. GENERAL GEOLOGY AND PREVIOUS STUDIES

The original geological survey of Raasay was carried out by Woodward in 1893, but significant additions were made to the Jurassic by Lee in 1920. The current British Geological Survey map of Raasay [Scotland Sheet 81(W)] is based on these surveys. Recently Bradshaw and Fenton (1982 p. 142) have produced a new map of central Raasay but this disagrees strongly with both the BGS map and my own mapping. Bradshaw and Fenton clearly relied too heavily on aerial photographs and not on field mapping.

The geology of central Raasay is complex and a summary of the stratigraphy is shown in table 1. A major fault (the Holoman-Screapadal Fault) of probable Tertiary age crosses central Raasay. This separates the Lewisian and Torridonian to the north from the Jurassic to the south.

The Lewisian Complex represents the crystalline basement and has had a complex geological history. It is moderately well exposed but has not previously been studied in detail.

The Torridonian is extensively exposed and represents a terrestrial sequence. At the base there are thin lacustrine siltstones, these are succeeded by thick braided stream sandstones. It has been studied in detail by Selley during the early 1960s (summary in Selley, 1987) but some of this work is in need of reinterpretation.

QUATERNARY	HOLOCENE		Peat
	PLEISTOCENE		Boulder Clay
UNCONFORMITY			
JURASSIC	MIDDLE		GREAT ESTUARINE GROUP
			BEARRERAIG SANDSTONE
	LIAS	UPPER	UNCONFORMITY
			RAASAY IRONSTONE
			UNCONFORMITY
			PORTREE SHALES
		MIDDLE	SCALPA SANDSTONE
		LOWER	PABBA SHALES
			BROADFORD BEDS
MAJOR UNCONFORMITY [not exposed]			
PRECAMBRIAN	LATE PROTEROZOIC		TORRIDONIAN
	MAJOR UNCONFORMITY		
	EARLY PROTEROZOIC AND ARCHAEAN		LEWISIAN

TABLE 1. Stratigraphical column for central Raasay.

The Jurassic consists of a lower marine sequence (Lias to Bearreraig Sandstone) followed by a fresh or brackish water sequence (Great Estuarine Group). The Lias deposits are present in the lower part of the east coast cliffs but exposures are better in southern Raasay (Lee, 1920). The Upper Lias however shows some differences. The Bearreraig Sandstone forms the upper part of these cliffs and also crops out in the west (Lee, 1920 and Morton, 1965, 1976). The enigmatic "Raasay Cornbrash" of Lee, 1920 has now been shown to represent part of the upper Bearreraig Sandstone (Bradshaw and Fenton, 1982). The Great Estuarine Group is exposed along the top of Raasay (Lee, 1920; Forsyth, 1960; Hudson, 1963 and Harris and Hudson, 1980).

The Brecciated Torridonian deposits have been mapped as volcanic vents on the BGS map. These breccias are not vents although their origin is unknown.

Tertiary igneous rocks are represented by dolerite dykes and sills and a granophyre sill. There are no extrusive igneous rocks.

The Quaternary is represented by glacial deposits (boulder clay and erratics) and peat.

3. THE LEWISIAN COMPLEX

The Lewisian Complex is exposed in northern Raasay and represents a plateau-like area of basement buried beneath the Torridonian. It consists of well foliated biotite and hornblende gneiss which is cut by amphibolitized Scourie dykes and microcline pegmatites. Two phases of metamorphism and at least four phases of folding are recognized. A summary of the geological evolution of the Lewisian of Raasay is shown in table 2; this is directly comparable with the evolution of the southern Lewisian of mainland Scotland (Park and Tarney, 1987).

THE BIOTITE AND HORNBLENDE GNEISS

The amphibolitized Scourie dykes show a small discordance with the foliation of the biotite and hornblende gneiss. This indicates that the Scourie dykes were intruded into an already foliated gneiss complex of presumed Scourian age. No other evidence of this early gneiss complex was found.

After the intrusion of the Scourie dykes, the early Laxfordian D3 event produced high amphibolite facies metamorphism and extensive ductile shearing. This shearing attenuated the D1 foliation and rotated it into D3 and produced a D3 foliation in the amphibolitized Scourie dykes. The foliation in the gneiss is defined by alternating layers rich in felsics (quartz and feldspar) and mafics (biotite and hornblende). Individual

EVENT		DEFORMATION	METAMORPHISM & STRUCTURES
POST LAXFORDIAN (?GRENVILLE)		D9	Development of N-S fault zones.
LAXFORDIAN	LATE	D8	Emplacement of aplitic veins along joints and small faults.
	MIDDLE	D7	Development of open, upright folds with E-W axes. Retrogressive metamorphism to upper greenschist or lower amphibolite facies. Development of small thrusts.
		D6	Development of asymmetrical, fairly tight folds with N-S to NW-SE axes.
		D5	Development of subangular, tight folds with N-S to NW-SE axes.
	EARLY	D4	Emplacement of microcline pegmatites cross-cutting D3 foliation and Scourie dykes.
		D3	Upper amphibolite facies metamorphism. Shearing of D1 foliation into D3 foliation. Development of D3 foliation in Scourie dykes. Mica fish fabrics develop in biotites. Localized injection of granites and early pegmatites. Development of isoclinal folds.
		D2	Intrusion of Scourie dyke swarm trending NW-SE.
SCOURIAN		D1	Formation of an early foliated grey gneiss complex.

TABLE 2: Evolution of the Lewisian Complex in Raasay.

layers have a width varying between 0.1 and 10cm. The biotites have been sheared producing muscovite fish along individual shear zones in the biotites, this is discussed in detail in appendix 1. The shearing has also produced a mineral lineation in the gneiss indicating the direction of shearing.

THE SCOURIE DYKE SUITE

The Scourie dykes represent dolerite dykes intruded into the early gneiss complex during a tensional regime. They have been metamorphosed and strongly deformed by ductile shearing and folding during the Laxfordian. They are now represented by moderately foliated amphibolite bodies up to 30m wide with a predominant NW-SE trend. The foliation is defined by thin layers rich in quartz and feldspar alternating with thicker layers rich in amphibole. The majority of these bodies are continuous and are locally folded; where the folding is more intense the incompetent amphibolites have been squeezed out and are discontinuous. One such discontinuous amphibolite body is exposed 300m east of Loch Beag (587 473). The early Laxfordian metamorphism has completely recrystallized the dykes destroying any remnants of igneous textures.

METAMORPHISM

Two metamorphic events are recognized in the Lewisian of Raasay; an early Laxfordian event and a late Laxfordian event. The early Laxfordian event produced high amphibolite facies metamorphism that has created an extensive hornblende-andesine metamorphic assemblage devoid of pyroxene. The late Laxfordian event is a localized retrogressive metamorphism to high greenschist or low amphibolite facies. According to Park and Tarney, 1987 (p. 20)

> "Laxfordian upright folds with NW-SE trend are ubiquitous ... and are associated on the mainland with retrogression to greenschist facies."

On Raasay this retrogression appears to be associated with D7 upright folds which trend E-W. The formation of thin veins of epidote is also associated with this late Laxfordian event. These metamorphic events are discussed in detail in appendix 1.

ACIDIC INTRUSIONS

ORTHOCLASE GRANITES Weakly foliated orthoclase granite forms only a minor component of the Lewisian Complex of central Raasay. 200m west of Tairbeart (588 477) there is a small exposure of red orthoclase granite and 150m south of Loch an Uachdair (583 467) there is a second patch of red orthoclase granite cut by a Scourie dyke. The granites are very weakly foliated, lack lineations and have an equigranular texture. Unfortunately the form of the granites could not be determined in the field. They probably represent anatectic granites emplaced late during the early Laxfordian D3 event. Since the granite near Loch an Uachdair is apparently cut by a Scourie dyke they may represent in situ melting of the biotite gneiss. In northern Raasay beyond the area mapped there are more extensive quantities of red orthoclase granite.

MICROCLINE PEGMATITES Coarse grained, unfoliated, microcline pegmatites abound throughout the Lewisian and range in width from veinlets 1mm wide to major veins 1m or more wide. They discordantly cut the amphibolitized Scourie dykes and the D3 foliation (figure 1c). They contain predominantly microcline and quartz with some plagioclase and a little biotite. Microcline crystals occasionally reach sizes of 0.5m or more. The intrusion of pegmatites began late in the Laxfordian D3 shearing event and these early pegmatites have been folded by D3 isoclinal folds (figure 1a). Most pegmatites were however emplaced after the D3 event and cut across the D3 foliation. The pegmatites have been folded by D5, D6 and D7 folds.

APLITIC VEINS After the Laxfordian folding, 1mm to 10mm wide aplitic veins were intruded into the Lewisian. They are not common but appear to be associated with joints and small faults (figure 1c). The biotite gneiss adjacent to some of these aplitic veins shows metasomatic discolouration. One vein cutting an amphibolite dyke on the foreshore 300m northeast of Brochel Castle (587 463) contains galena mineralization.

FOLDING

At least four phases of folding can be recognized in the Lewisian of Raasay. This folding has strongly deformed the D3 foliation on such a small scale that synforms and antiforms cannot be mapped on a scale of 6 inches to 1 mile.

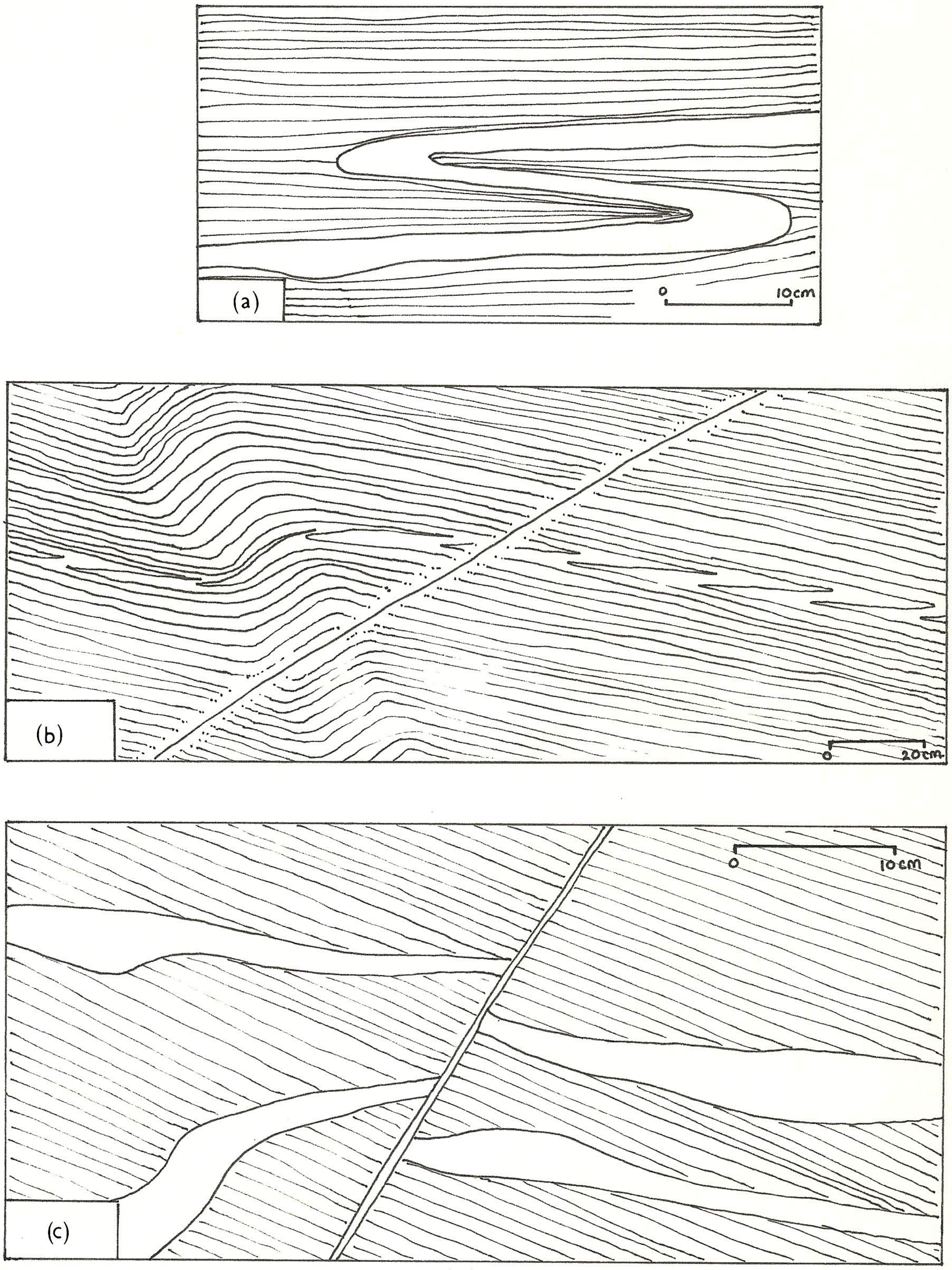


Figure 1. Lewisian structures. (a) Isoclinal D3 fold with axial planar D3 foliation folding early pegmatite. Road, 400m E of Loch Beag (588 472). (b) Rounded D6 fold refolding angular D5 fold in biotite gneiss. Cut by late joint along which leaching has occurred, 700m N of Brochel Castle (585 469). (c) Foliated amphibolite cut by D4 pegmatites and D8 aplitic vein emplaced along a small fault. Road, 400m N of Brochel Castle (585 466).

D3 FOLDS Isoclinal drag folds developed during the D3 shearing. They are not common since they have been mainly sheared out. Occasionally D3 folds are seen where an early pegmatite has been folded, in such cases the D3 foliation is axial planar to the fold, see figure 1a.

D5 FOLDS These are angular to subangular, similar style folds that have been refolded by the more rounded D6 folds. D5 folds are flat lying, tight folds with subhorizontal axes trending N-S to NW-SE. See figure 1b.

D6 FOLDS These are the most common folds developed and are represented by asymmetrical, fairly tight, flat lying folds with subhorizontal axes trending N-S to NW-SE. D5 and D6 folds are difficult to distinguish unless they are superimposed. D6 folds are shown in figure 1b and plates 1 and 2.

D7 FOLDS Gently inclined to upright folds which are open and have subhorizontal axes trending E-W. These folds are fairly common and are associated with the retrogressive metamorphism. Biotites may occasionally be rotated into alignment with the axial planes of D7 folds. Indications of a D7 fold are shown in plate 2.

Figure 2 shows a stereogram of all axes measured for D5, D6 and D7 folds. It can be seen that some axes do not correspond to any of the folds described above and some additional phases of folding may be present.

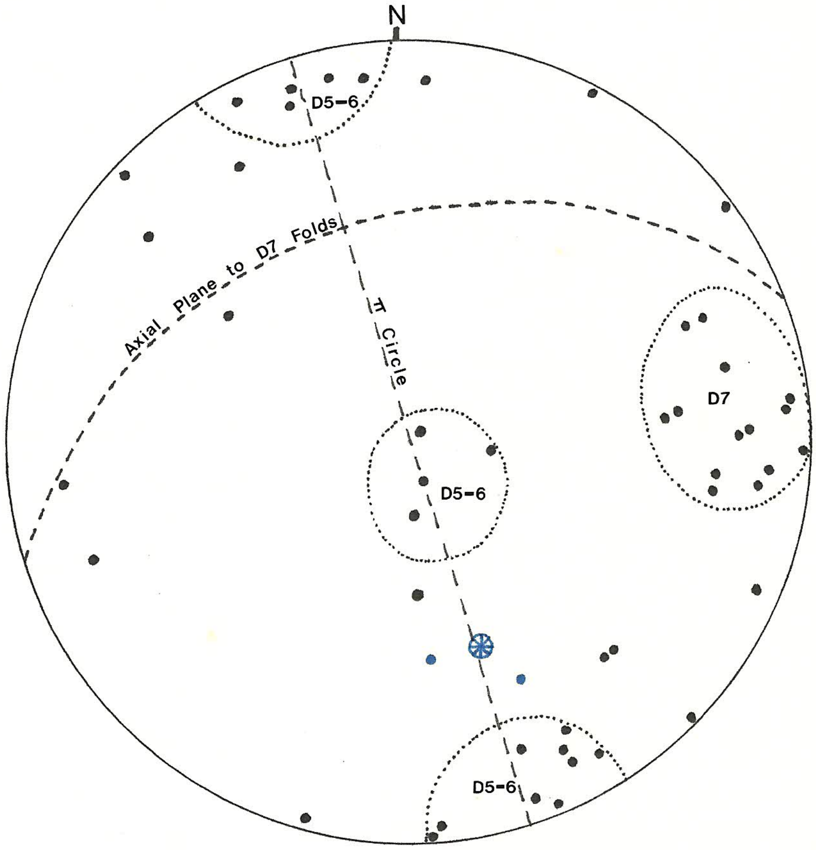
PLATE 1

PLATE 1A. D6 fold in biotite gneiss. Foreshore 300m NE of Brochel Castle (587 464). Pencil is 15cm long.

PLATE 1B. Sheath fold in biotite gneiss. Formed by two phases of folding, D6 and ?D7. Foreshore 350m NE of Brochel Castle (587 464). Pencil is 15cm long.

PLATE 2

PLATE 2. Folded amphibolite dyke. Note indications of discordance between biotite gneiss and dyke. Upper photograph. Large D6 fold tightened and slightly refolded by gentle, upright D7 fold (trace axial surface). Book is 25cm high. Lower photograph. Detail showing lower right fold hinge. Note poorly preserved D5 fold in hinge zone. Pencil is 15cm long. Vertical face 500m NE of Brochel Castle (588 466).



- Fold axis.
- Cleavage defined by rotated biotites.
- Pole to axial plane of D7 folds.

Figure 2. Stereographic projection for all D5, D6 and D7 folds in the Lewisian. D5-D6 folds have the same trend and cannot be distinguished. D7 folds refold D5-D6 folds and develop an axial planar cleavage. Some fold axes do not show D5, D6 or D7 trends and may represent additional phases of folding.

FAULTING

500m north of Brochel Castle (585 467) there is a small thrust developed in the Lewisian (plate 3). The thrust represents a structural discontinuity between the vertically foliated amphibolite in the hanging wall and the gently dipping biotite gneiss in the foot wall. The thrust plane dips at 13° towards 148° and has a mineral lineation trending 152°. This suggests that the thrust is most likely associated with the D7 phase of folding.

100m west of Tairbeart (588 477) there is a 3m wide, subvertical fault zone that trends 314°. The numerous small faults belonging to this fault zone have extensive fault breccias cemented by calcite. The fault zone forms a ravine running both inland and out to sea. Joints with a similar trend, N-S to NW-SE are fairly common in the Lewisian. The age of these faults and joints is difficult to determine. They postdate the Laxfordian event and are very tentatively referred to the Grenville event which produced E-W and NE-SW faults in southern Greenland (even though the fault trends are different).

COMPARISON WITH THE LEWISIAN OF SOUTHERN MAINLAND SCOTLAND

The Lewisian of Raasay shows a similar evolution to that of southern mainland Scotland (Park and Tarney, 1987). The only difference appears to be the development of more phases of Laxfordian folding on Raasay.

PLATE 3

PLATE 3. Small thrust in the Lewisian. The thrust plane forms the ledge about two thirds of the way up the cutting and can be clearly seen in the photograph. The thrust plane dips at 13° towards 148° and has a lineation trending 152° indicating the direction of movement. The hanging wall is composed of amphibolite with a vertical foliation, the foot wall of biotite gneiss with a gently dipping foliation. A Tertiary dolerite dyke is present in the lower part of the cutting, it strikes NNE and has a dip of 40°. It is probably emplaced along a weakness in the rock associated with the thrust. Road cutting 500m N of Brochel Castle (585 467). The shaft of the hammer sitting on the dyke has a length of 0.3m.

4. THE TORRIDONIAN

The Torridonian is extensively exposed in central Raasay north of the Screapadal-Holoman fault. It dips at about 20° towards the west and has been very gently folded. The Diabaig and Applecross Formations of the Torridon Group are represented and unconformably overlie a buried topography of Lewisian gneiss. This topography consists of a plateau area lying to the north, more or less equivalent to the present outcrop of the Lewisian and lowland lying to the south and west. Selley, 1965b (p. 364) has subdivided the Torridonian of Raasay into a number of lithostratigraphical units and facies types. These are shown in tables 3 and 4.

BASAL FACIES — ALLUVIAL FAN, CLIFF SCREE AND BEACH DEPOSITS.

The basal facies of central Raasay is of very limited distribution and only found adjacent to and overlying the Lewisian. It consists dominantly of breccias, conglomerates and sandstones with only small amounts of siltstone. The detritus consists entirely of Lewisian material and was derived locally from the Lewisian plateau. The basal facies represent the lateral (marginal) equivalents of the grey and red facies and possibly deposits older than the grey facies. Two separate environments can be recognized.

		LITHOSTRATIGRAPHICAL UNITS	
		AFTER SELLEY 1965	TERMS USED HEREIN
TORRIDON GROUP	APPLECROSS FORMATION	GLAME BEDS	GLAME SANDSTONE
	DIABAIG FORMATION	LOCH AN UACHDAIR BEDS	LOCH AN UACHDAIR SANDSTONE
		BROCHEL BEDS	BROCHEL SILTSTONE

TABLE 3. Lithostratigraphical units of the Torridonian of Raasay.

FACIES TYPES	
AFTER SELLEY 1965	FACIES USED HEREIN
RED FACIES Braided rivers.	**RED FACIES** Braided rivers.
GREY FACIES Shallow water lacustrine or marine shoreline.	**GREY FACIES** Shallow water non-marine lake.
BASAL FACIES Scree and fanglomerate.	**BASAL FACIES** Alluvial fan, cliff scree and beach.

TABLE 4. Facies types of the Torridonian of Raasay.

1 ALLUVIAL FAN DEPOSITS

On the coast about 100m north of Brochel Castle (587 464) 4m of conglomerates, breccias and sandstones are exposed backed up against and overlying features in the Lewisian. The clasts are predominantly angular (Plate 4A) but occasional well rounded clasts do occur. The clasts consist of amphibolite, biotite gneiss and pegmatite. They have an average size of 1 to 10cm but occasionally reach a size of 1m. The clasts are generally concentrated in bands and alternate with beds of greenish grey sandstone. Small scale cross-bedding is developed in a few sandstone beds but most are either massive or have parallel laminations. Thin beds of reddish grey micaceous siltstone up to 2cm thick are present interbedded with the sandstones (Plate 4B). These siltstones have been folded beneath larger clasts by compaction. This is interpreted as a cliff scree alluvial fan deposit. It is the lateral equivalent of the grey facies but the contact between the two is not seen. It could in part be older than the grey facies.

The small valley running southeast from Loch an Uachdair (585 467) is floored by coarse breccias and sandstones overlying the Lewisian, plate 5A. The clasts are angular to subangular and consist of amphibolite, biotite gneiss and pegmatite. They average 1 to 10cm in size but occasional clasts up to 50cm in size occur. Clast support breccias alternate with crudely cross-bedded greyish sandstone. A few thin micaceous, reddish grey siltstone bands up to 2cm thick are also present. The distinct bedding and clast support breccias indicate an alluvial fan deposit.

PLATE 4

PLATE 4A. Basal Torridonian. Very angular clasts of Lewisian gneiss in cliff scree deposit. Foreshore 300m ENE of Brochel Castle (587 464). Pencil is 15cm long.

PLATE 4B. Thin micaceous siltstone bands interbedded with poorly sorted coarse grained sandstone. The curvature of the siltstone bands is due to subsequent compaction. Basal Torridonian. Alluvial fan deposit. Small cliff 200m NE of Brochel Castle (586 463). Pen is 12cm long.

PLATE 5

PLATE 5A. Basal Torridonian resting unconformably on Lewisian gneiss. The Torridonian consists of a poorly sorted breccia of Lewisian clasts in a matrix of coarse grained sandstone. Alluvial fan deposit. Road cutting 600m N of Brochel Castle (585 467). Hammer shaft is 0.3m long.

PLATE 5B. Plan view showing rounded clasts of amphibolite in a clast support fabric cemented by fine grained sandstone. Probably a beach deposit. 400m NW of Brochel Castle (582 466). Pencil is 15cm long.

2 BEACH DEPOSITS

About 500m northwest of Brochel Castle (582 466) a coarse clast support conglomerate is exposed overlying a platform cut in the Lewisian, plate 5B. The clasts are mainly composed of amphibolite but clasts of biotite gneiss also occur. They are well rounded, well sorted and have an average size of 30cm. The matrix consists of well cemented greenish grey siltstone. The well rounded, well sorted clasts and the platform cut into the Lewisian suggest a beach deposit.

THE BROCHEL SILTSTONE — GREY FACIES

The Brochel Siltstone consists dominantly of siltstone but also contains sandstones and a few breccias. Stewart and Parker, 1978 used the boron content of illite to show that the Diabaig grey shales are non-marine lake deposits, a conclusion also drawn by Selley working on the sedimentary structures in Raasay (Selley, 1965a p. 379). The Brochel Siltstone was deposited in the lowland area adjacent to the Lewisian plateau and the best exposures occur on the coast south of Brochel Castle. At Brochel calculations suggest a thickness of 280m for the Brochel Siltstone. A representative log of part of the Brochel Siltstone is shown in figure 3.

SILTSTONE

Parallel laminated, grey, micaceous siltstone with occasional beds of unidirectional and herringbone cross-bedded siltstone. Symmetrical ripples are common, plate 6A and have an average wavelength of 5cm. They occur both within the siltstones and on the top of thin sandstone beds. These ripples indicate a NW-SE palaeocurrent.

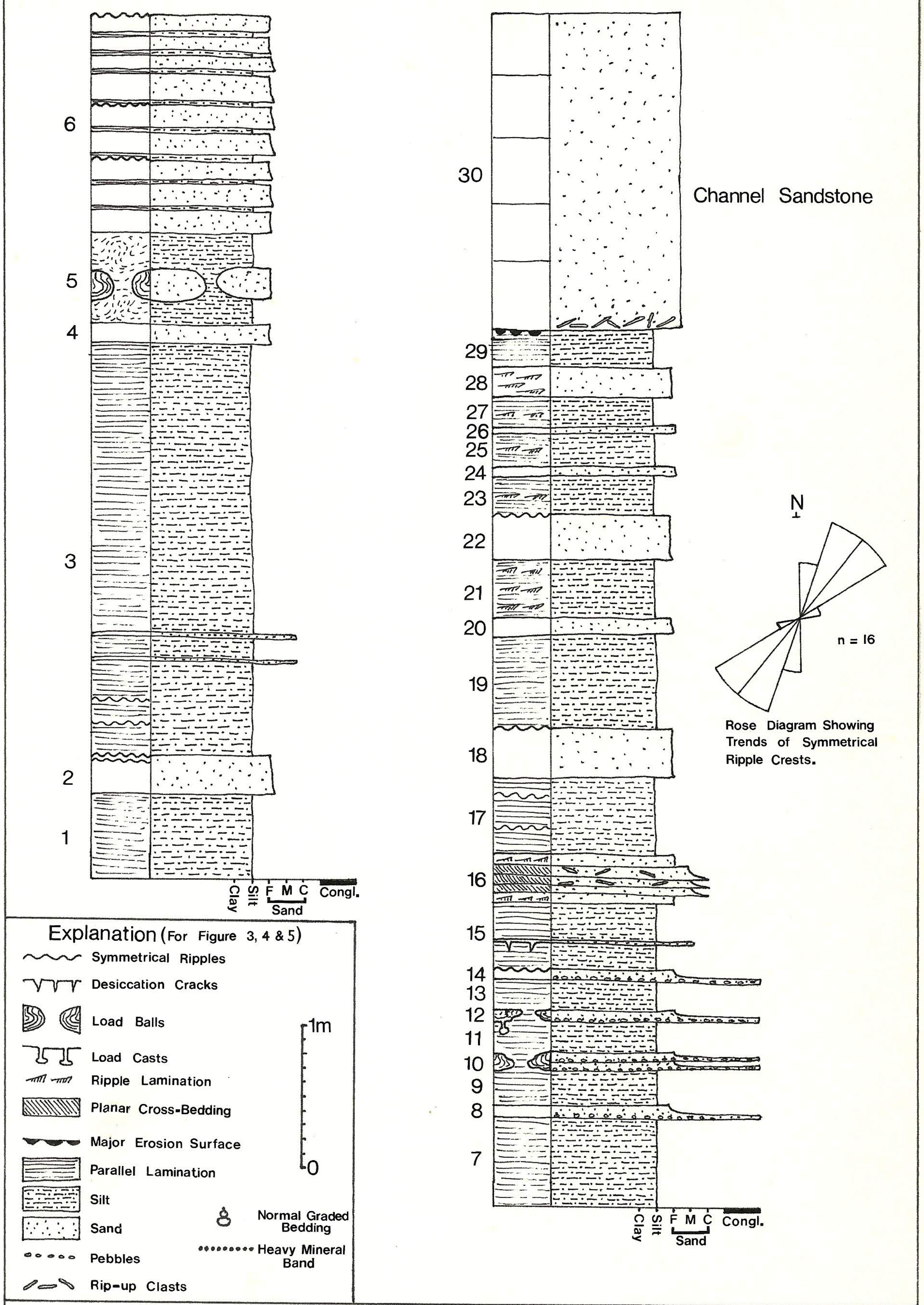


Figure 3. Representative section through the Brochel Siltstone (grey facies). Foreshore 500m S of Brochel Castle (584 458).

PLATE 6

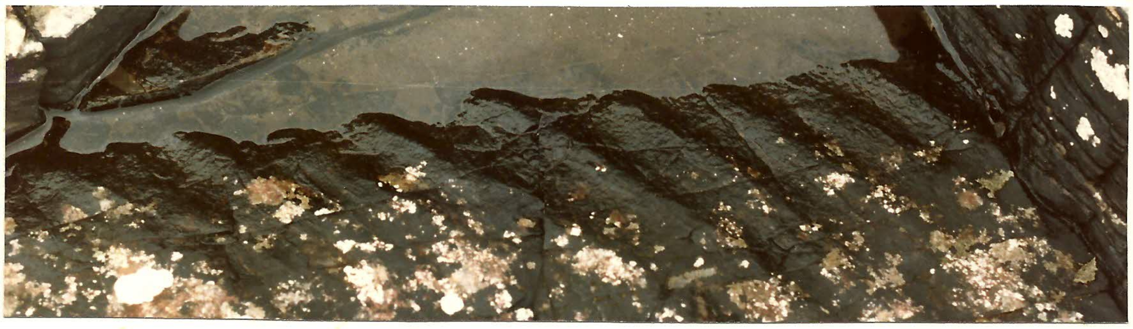


PLATE 6A. Straight crested, symmetrical ripples on the top of a medium grained, grey sandstone unit. Ripple wavelength is 6cm. Brochel Siltstone. Foreshore 500m S of Brochel Castle (584 458).

PLATE 6B. Thick channel sandstone cutting Brochel Siltstone. This shows extensive dish-shaped structures due to slumping. The slumping is restricted to the lower beds and the upper beds have planar surfaces unaffected by slumping. Foreshore and clifftop 400m S of Brochel Castle (584 459). The posts on the clifftop are 1m high.

In the uppermost 80m of the Brochel Siltstone, symmetrical ripples disappear and there is a colour change. The grey siltstones typical of the lower part of the Brochel Siltstone pass up into red and reddish grey siltstone with occasional tea-green laminae. This shows a transition from the grey facies to the red facies.

SANDSTONE

Three different types of sandstone unit are found in the Brochel Siltstone of Raasay.

TYPE I. COARSE GRAINED SANDSTONE. (Figure 4a).

Thin beds of coarse grained sandstone between 5 and 15cm thick are fairly common in the Brochel Siltstone. They consist of a coarse grained, clast support basal portion with angular to subangular clasts set in a coarse grained sandstone matrix. The clasts are composed of Lewisian material and have an average size of 0.3 to 2.0cm. A few large clasts up to 10cm in size may also be present. This basal portion may be massive or have poorly developed parallel laminations. The upper portion consists of coarse to fine grained, normally graded sandstone usually with unidirectional ripple lamination towards the top. The top surface of many units have symmetrical ripples indicating subsequent wave reworking. The large, angular Lewisian clasts indicate a local provenance and these units probably represent material carried down from the Lewisian plateau during rainstorms. The "Brochel mudflow" described by Selley, 1965a (p. 375) represents a Type I sandstone strongly affected by soft sediment deformation (see below).

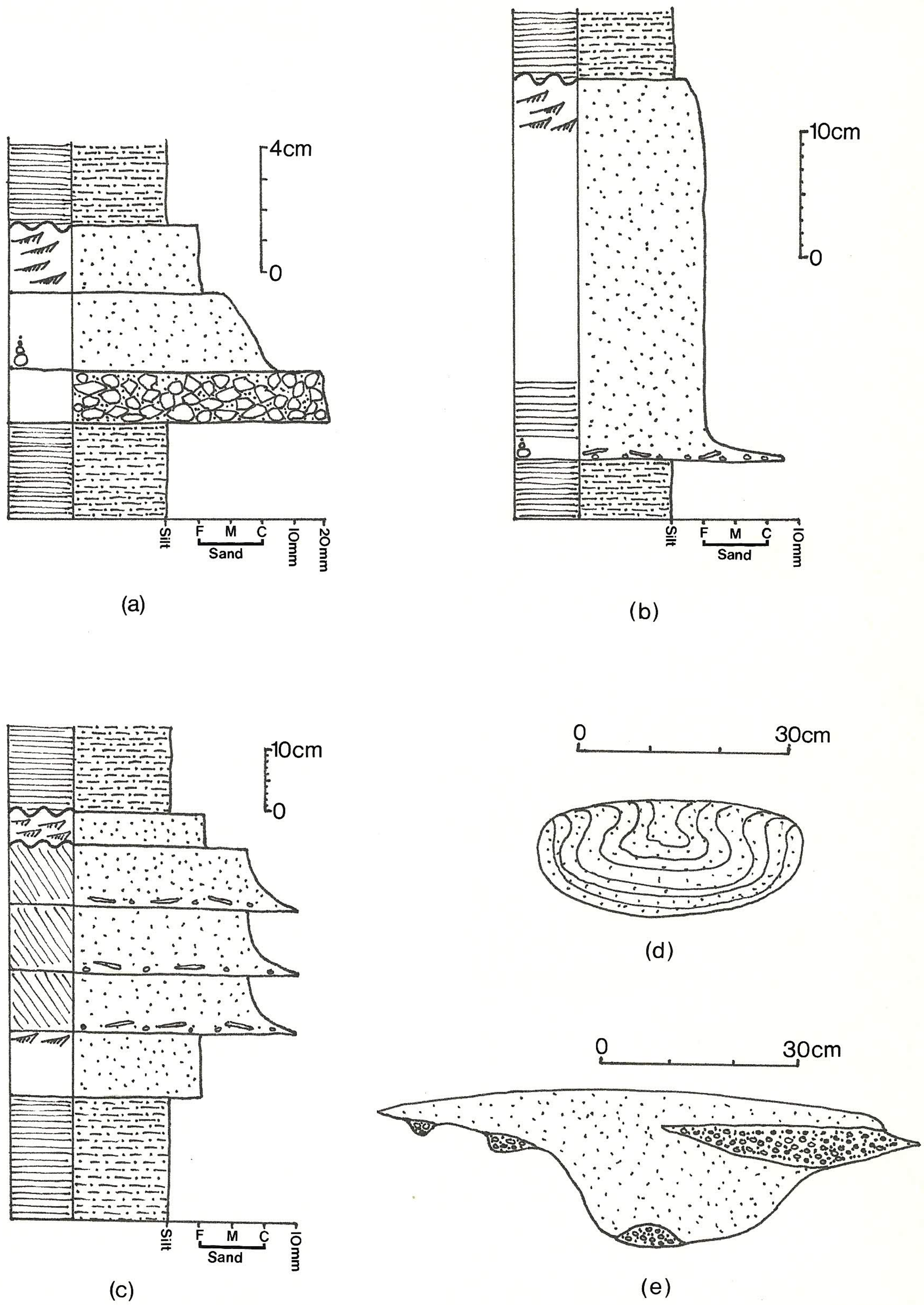


Figure 4. Sedimentary structures in the Brochel Siltstone.
(a) Type I coarse grained sandstone unit. (b) Type II fine grained sandstone unit. (c) Composite sandstone unit composed of type I and type II sandstones. (d) Load ball of fine grained sandstone. (e) Irregular load ball of conglomeratic and fine grained sandstone. (a)-(e) Foreshore 500m S of Brochel Castle (584 458). For key to symbols see figure 3.

TYPE II. MEDIUM GRAINED GREY SANDSTONES. (Figure 4b).

Medium grained, grey sandstone in units 10 to 40cm thick. The basal 1cm may show normal grading from coarse to medium grained sandstone. A few small, rounded Lewisian pebbles or siltstone rip-up clasts may be present in a basal lag. These sandstones are mainly massive but sometimes show planar cross bedding or parallel laminations. Unidirectional ripple laminations may be present in the upper part and the tops are often reworked by wave action producing symmetrical ripples. Selley, 1987 (p. 51) remarked on the similarity of these sandstones to turbidites but I interpret them as sheet flood deposits (Tucker, 1978 p.177)

TYPE III. PINK CHANNEL SANDSTONE.

1 to 5m thick, well sorted, medium to coarse grained sandstones. The base is strongly erosive and a basal lag with rounded Lewisian pebbles and siltstone rip-up clasts is usually developed. Individual beds are 0.5 to 1.5m thick and have well developed planar cross bedding. Slumping is very common, plate 6B and strongly deforms the bedding and cross bedding. These sandstones represent distributary channels to braided rivers.

SOFT SEDIMENT DEFORMATION

SLUMPING. This is widespread in the channel sandstones and has produced overturned foresets, sedimentary folds and dish shaped structures (Plate 6B).

LOAD CASTS AND LOAD BALLS. Load casts are developed on the base of several type I sandstone units. The large difference in grainsize between the type I sandstones and the siltstones has resulted in the formation of unusual load casts. On the base of one coarse grained sandstone unit (the "Brochel mudflow" of Selley, 1965a p. 375) load casts are developed with a relief of 10cm, plate 7B. Two horizons of load balls are also present. The first consists of regular elliptical balls, 30 to 40cm long composed of medium grained sandstone (Plate 7A and figure 4d). The second consists of irregularly shaped balls, 2 to 80cm long composed of medium and very coarse grained sandstone (Figure 4e). The irregular shape of these load balls is again due to the difference in grainsize.

The presence of extensive slumping and load structures indicates that the area was tectonically unstable during sedimentation and subject to external shocks (earthquakes).

THE GLAME SANDSTONE AND LOCH AN UACHDAIR SANDSTONE—RED FACIES.

The base of the Loch an Uachdair Sandstone is taken as the point where red sandstones become the dominant lithology. This is a rather marked change and can be easily mapped.

The base of the Glame Sandstone (Applecross Formation) is defined as the first appearance of pebbles of non-Lewisian origin (Selley, 1965b p. 363). This horizon is more difficult to map but seems to coincide with an increase in grainsize in the lower part of channel fill sequences.

Calculations indicate that the Loch an Uachdair Sandstone is about 350m thick and 650m of the Glame Sandstone are present in the area surveyed.

PLATE 7

PLATE 7A. Band of load balls composed of fine grained, grey sandstone. Section is typical of the Brochel Siltstone and shows alternating layers of grey, micaceous siltstone and fine to medium grained, grey sandstone. Foreshore 500m S of Brochel Castle (584 458). Pencil is 15cm long.

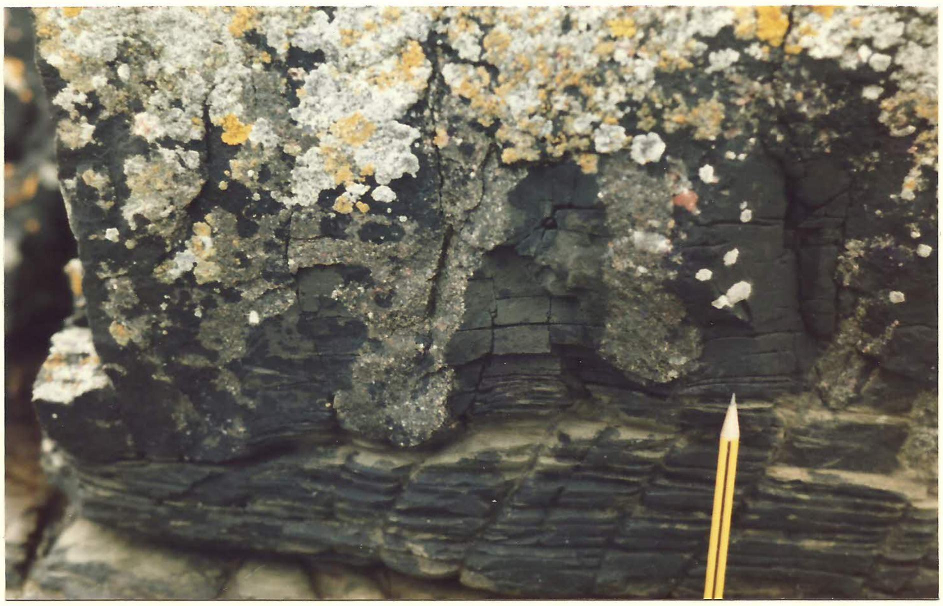


PLATE 7B. Load casts developed on the base of a coarse grained sandstone unit. Brochel Siltstone. Foreshore 300m SE of Brochel Castle (586 461). Portion of pencil visible is 10cm long.

The red facies consists of 2 to 12m thick channel fill sequences. These consist of medium and coarse grained, well sorted, red sandstones in beds 0.2 to 1.5m thick. The beds may be massive, parallel laminated or have planar cross bedding. The parallel laminated beds that occur in the lower parts of channel fill sequences have primary current lineation and sometimes heavy mineral bands. The heavy minerals are primarily opaque iron oxides but epidote also occurs. Siltstone is of limited occurrence but may be present in the upper part of channel fill sequences. It usually has unidirectional ripples (Plate 8B) and is often associated with desiccation cracks (Plate 9B). The bases of channel fill sequences are strongly erosive with extensive lags containing rounded pebbles and siltstone rip-up clasts (Figure 5A). Logs of channel fill sequences are shown in figure 5.

Many sandstone sequences show extensive slumping. Slumps vary in size from small folds (Plate 8A) to major deformed regions up to 50m long (Plate 10A). In many cases slump folds have been planed off by subsequent sandstone beds (Plate 10B). Selley et al, 1963 (p. 224) considered these structures were

> "formed more or less in situ by the shifting and rearrangement of quicksands."

I reject this and consider that the structures are primarily the result of slumping although dewatering may have caused some subsequent deformation.

A limited number of palaeocurrent readings were obtained from planar cross bedding, figure 6. These indicate a palaeocurrent towards the south (corrected for tectonic dip). The axes of three slump folds were also measured, and are consistent with a

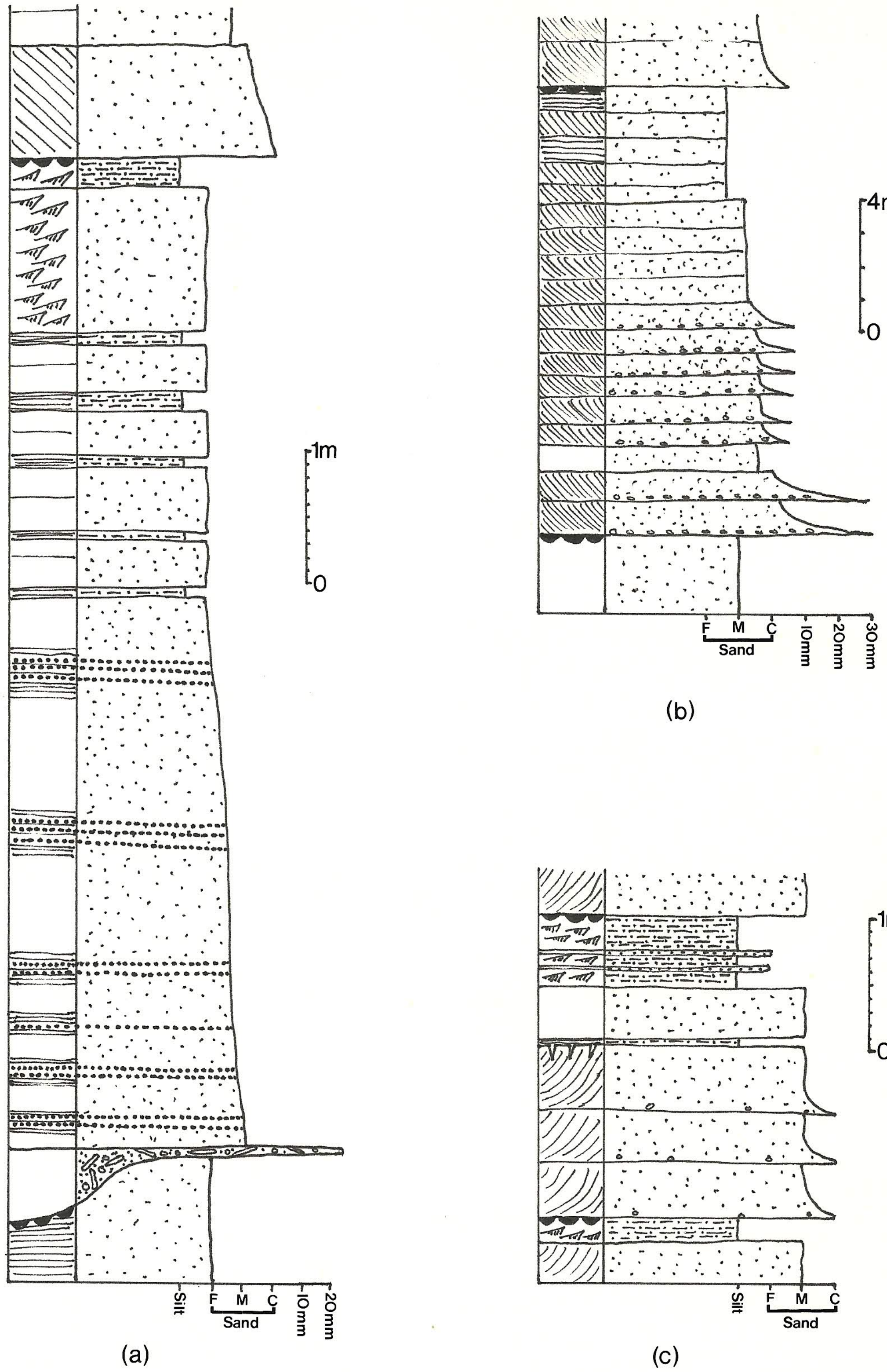


Figure 5. Glame Sandstone and Loch an Uachdair Sandstone (red facies). Typical braided stream sequences. (a) Sequence with heavy mineral bands in lower part. Road cutting 500m S of Loch na Bronn (577 460). Loch an Uachdair Sandstone. (b) Coarse grained sequence, mainly cross bedded. Bay 800m E of Manish Point (576 481). Glame Sandstone. (c) Sequence with desiccation cracks. Bay 1km E of Manish Point (579 482). Glame Sandstone. For key to symbols see figure 3.

PLATE 8

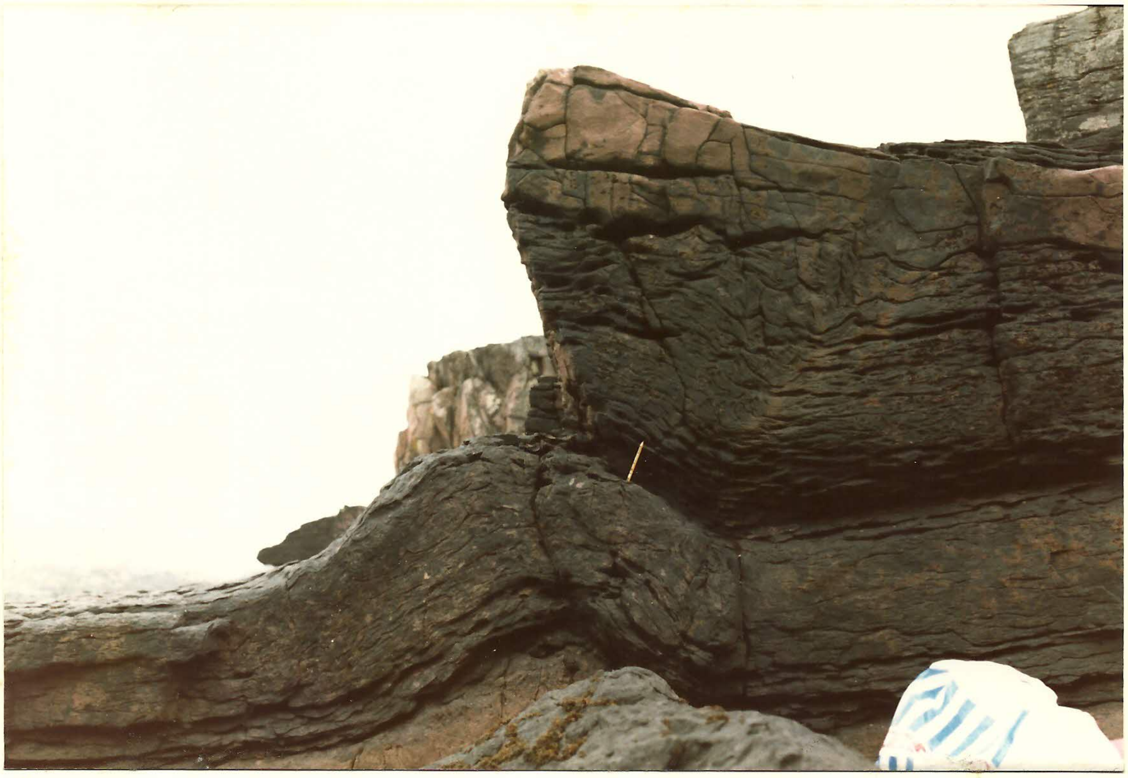


Plate 8A. Synsedimentary fold developed in siltstone band. Loch an Uachdair Sandstone. Foreshore 1.3km E of Manish Point (582 482). Pencil is 15cm long.

Plate 8B. Climbing ripples in siltstone band. Loch an Uachdair Sandstone. Small promontory 1.3km E of Manish Point (582 482). Pencil is 15cm long.

PLATE 9

Plate 9A. Disrupted blocks of siltstone in apparently undeformed sequence. This is due to bedding plane slip at the base of a large slump. Foreshore 1.1km E of Manish Point (580 482). Pencil is 15cm long.
Loch an Uachdair Sandstone.

Plate 9B. Polygonal shrinkage cracks on upper surface of a sandstone bed. Glame Sandstone. Bay 1km E of Manish Point (577 482). Pencil is 15cm long.

PLATE 10

Plate 10A. Large slump fold developed in Loch an Uachdair Sandstone. Note deformed cross bedding. Small promontory 1.2km E of Manish Point (581 483). Notebook is 25cm high.

Plate 10B. Slump fold developed in Glame Sandstone that has been planed off by sandstone bed above. Small canyon 1km E of Manish Point (578 483). Notebook is 25cm high.

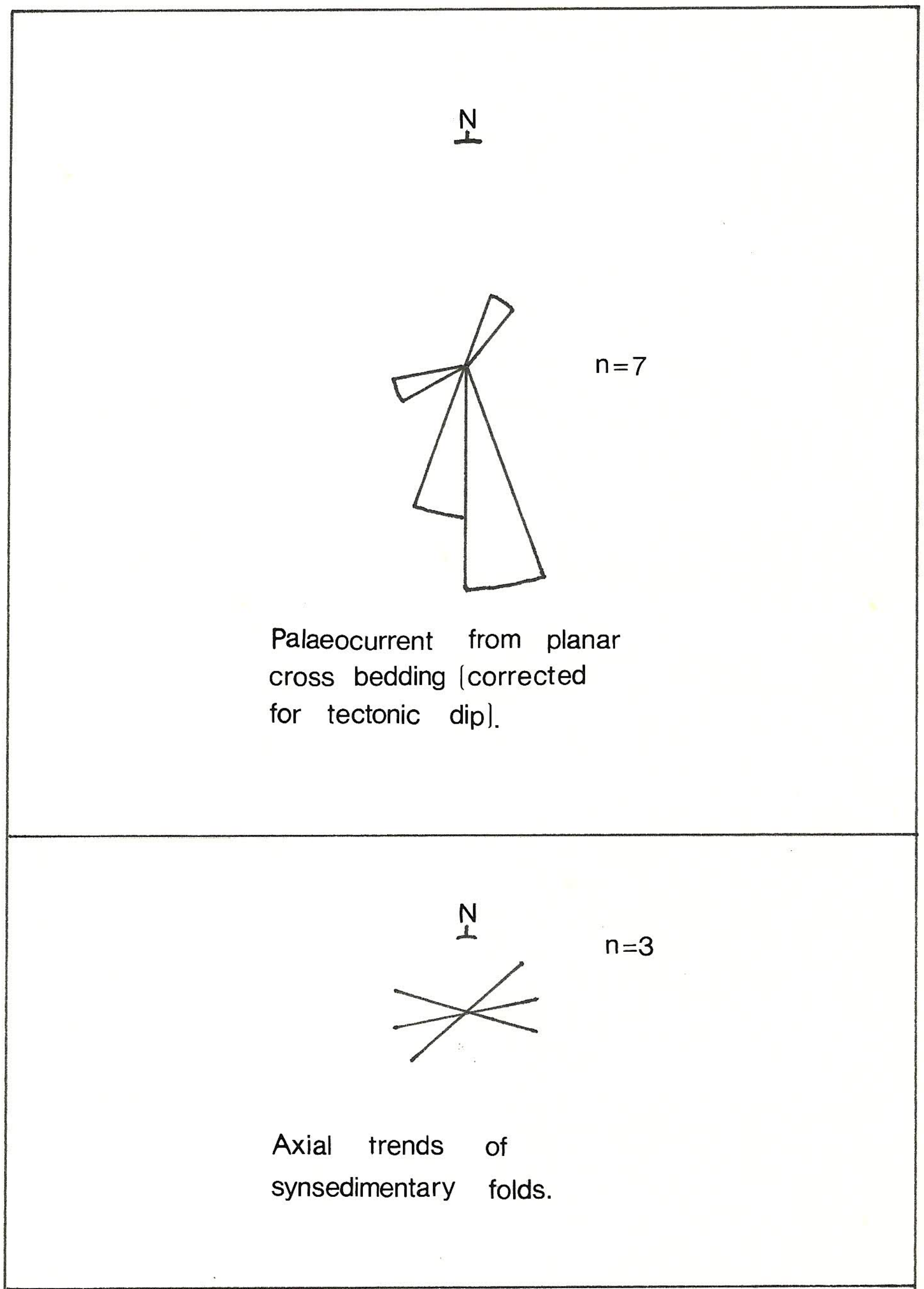


Figure 6. Palaeocurrents from the red facies of the Torridonian. Planar cross bedding indicates a palaeocurrent towards the south. This is consistent with the synsedimentary fold axes which are perpendicular to flow.

southerly palaeocurrent. These results differ from those of Selley, 1965a (p. 378) and since my sample is small it should be regarded tentatively.

RED FACIES INTERPRETATION

The poorly developed fining upwards sequences and the lack of fines indicates we are dealing with a braided river system. Selley, 1965a (p. 371) thought that there were occasional returns to grey facies environments during the red facies. These bands of grey siltstone do not however show grey facies characteristics. Instead they have unidirectional ripples (Plate 8B) and are sometimes associated with desiccation cracks. This indicates that they represent either bar top deposits or channel abandonment deposits.

5. THE JURASSIC

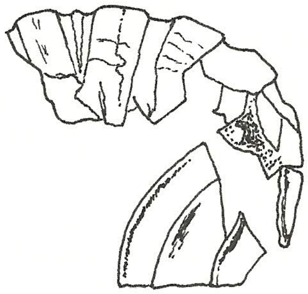
The Jurassic is exposed south of the Screapadal-Holoman fault and dips between 10° and 20° towards the west. It has been intruded by a series of Tertiary sills. In central Raasay the boundary between the Torridonian and the Jurassic is faulted and the basal Jurassic if present, is not exposed. The succession present is shown in table 5.

BROADFORD BEDS.

These are only exposed in the fault bounded block at South Screapadal. Exposures are very poor and limited to two partially grassed over banks along the south side of An Leth-allt (579 442 and 581 444). They show the typical cycles developed in the Broadford Beds of southern Raasay (Hallaig Shore) and Skye (Broadford and Breckish). Grey, micaceous shales and siltstones alternate with grey, calcareous sandstones and occasional grey, sandy limestones. These cycles are 0.5 to 1.5m thick and about ten such cycles can be made out. Gryphaea arcuata obliqua occurs in abundance (figure 7c) but no other fossils were found. Lee, 1920 (p. 16) assigned these beds to the early Sinemurian by comparison with the Hallaig Shore sections. No Hettangian or later Sinemurian deposits are exposed in central Raasay. These exposures are strongly affected by small faults and many of the gryphaeas have been crushed. This is due to the close proximity of the Screapadal-Holoman fault which runs along An Leth-allt.

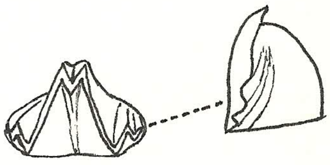
	STAGE	AMMONITE ZONES	SUCCESSION IN CENTRAL RAASAY		
MIDDLE JURASSIC	BATHONIAN	NON—MARINE	NO CORRELATION WITH STANDARD POSSIBLE	DUNTULM FM.	GREAT ESTUARINE GROUP
MIDDLE JURASSIC	BATHONIAN	NON—MARINE	NO CORRELATION WITH STANDARD POSSIBLE	VALTOS SST. FM.	GREAT ESTUARINE GROUP
MIDDLE JURASSIC	BATHONIAN	NON—MARINE	NO CORRELATION WITH STANDARD POSSIBLE	LEALT SHALE FM.	GREAT ESTUARINE GROUP
MIDDLE JURASSIC	BATHONIAN	NON—MARINE	NO CORRELATION WITH STANDARD POSSIBLE	ELGOL SST. FM.	GREAT ESTUARINE GROUP
MIDDLE JURASSIC	BAJOCIAN	parkinsoni	NO CORRELATION WITH STANDARD POSSIBLE	CULLAIDH SHALE FM.	GREAT ESTUARINE GROUP
MIDDLE JURASSIC	BAJOCIAN	garantiana	GARANTIANA CLAY MBR.		BEARRERAIG SANDSTONE FM.
MIDDLE JURASSIC	BAJOCIAN	subfurcatum	RAASAY SST. MBR.		BEARRERAIG SANDSTONE FM.
MIDDLE JURASSIC	BAJOCIAN	humphriesianum	RAASAY SST. MBR.		BEARRERAIG SANDSTONE FM.
MIDDLE JURASSIC	BAJOCIAN	sauzei	RAASAY SST. MBR.		BEARRERAIG SANDSTONE FM.
MIDDLE JURASSIC	BAJOCIAN	laeviuscula	RAASAY SST. MBR.		BEARRERAIG SANDSTONE FM.
MIDDLE JURASSIC	BAJOCIAN	discites	BEINN NA LEAC SST. MBR.		BEARRERAIG SANDSTONE FM.
MIDDLE JURASSIC	AALENIAN	concavum	BEINN NA LEAC SST. MBR.		BEARRERAIG SANDSTONE FM.
MIDDLE JURASSIC	AALENIAN	murchisonae	BEINN NA LEAC SST. MBR.		BEARRERAIG SANDSTONE FM.
MIDDLE JURASSIC	AALENIAN	opalinum	BEINN NA LEAC SST. MBR. / DUN CAAN SHALES MBR.		BEARRERAIG SANDSTONE FM.
LOWER JURASSIC	TOARCIAN	levesquei			
LOWER JURASSIC	TOARCIAN	thouarsense	RAASAY IRONSTONE		
LOWER JURASSIC	TOARCIAN	variabilis			
LOWER JURASSIC	TOARCIAN	bifrons			
LOWER JURASSIC	TOARCIAN	falciferum	PORTREE SHALES		
LOWER JURASSIC	TOARCIAN	tenuicostatum	SCALPA SANDSTONE		
LOWER JURASSIC	PLIENSBACHIAN	spinatum	SCALPA SANDSTONE		
LOWER JURASSIC	PLIENSBACHIAN	margaritatus	SCALPA SANDSTONE		
LOWER JURASSIC	PLIENSBACHIAN	davoei	SCALPA SANDSTONE		
LOWER JURASSIC	PLIENSBACHIAN	ibex	SCALPA SANDSTONE	NOT EXPOSED IN CENTRAL RAASAY	
LOWER JURASSIC	PLIENSBACHIAN	jamesoni	PABBA SHALES	NOT EXPOSED IN CENTRAL RAASAY	
LOWER JURASSIC	SINEMURIAN	upper	PABBA SHALES	NOT EXPOSED IN CENTRAL RAASAY	
LOWER JURASSIC	SINEMURIAN	lower	UPPER BROADFORD BEDS	NOT EXPOSED IN CENTRAL RAASAY	
LOWER JURASSIC	SINEMURIAN	lower	LOWER BROADFORD BEDS		
LOWER JURASSIC	HETTANGIAN	upper	?	?	
LOWER JURASSIC	HETTANGIAN	lower			

TABLE 5. Jurassic succession in central Raasay



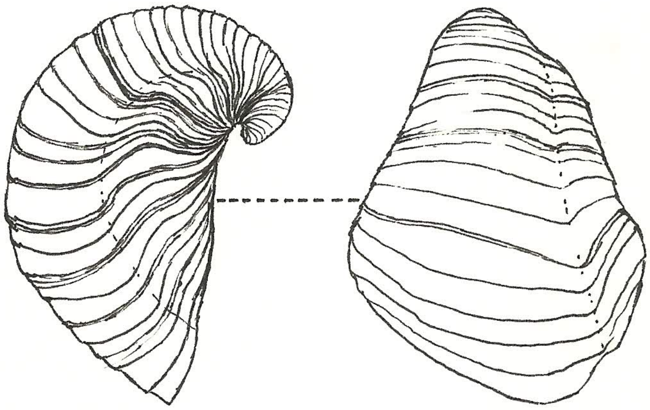
(a)

Glyphea sp. Abdomen. X1.5
Upper ibex or lower davoei zone. Lower Scalpa Sandstone.



(b)

Homoeorhynchia capitulata (Tate). X1. Specimen showing a fold resembling H. cynocephala (Richard) from the upper Toarcian. Upper ibex or lower davoei zone. Lower Scalpa Sandstone.



(c)

Gryphaea arcuata obliqua
X1. Lower Broadford Beds. Early Sinemurian.

Figure 7. Fossils from the Lower Lias. (a) and (b) from the lower Scalpa Sandstone, wave cut platform 1.6km south of South Screapadal (587 425). (c) from the Broadford Beds, bank on south side of An Leth-allt, near Screapadal (579 442).

PABBA SHALES.

No exposures of the Pabba Shales were found although it is possible that they may be present in the western part of the fault bounded block at South Screapadal. Lee, 1920 (p. 24) recorded possible Pabba Shales on the foreshore below Druim an Aonaich (587 425) but these belong to the lower Scalpa Sandstone.

SCALPA SANDSTONE.

The Scalpa Sandstone forms the lower part of the cliff below Druim an Aonaich. Much of the lower cliff is however covered by talus derived from the Bearreraig Sandstone and exposures of the Scalpa Sandstone are poor.

The lower Scalpa Sandstone is exposed in a series of wave cut platforms on the foreshore below Druim an Aonaich, 1.6km south of South Screapadal (587 425). About 15m of grey, micaceous siltstones and sandstones are present in coarsening upwards cycles 1 to 2m thick. The base of the cycle consists of grey, laminated siltstone which coarsens upwards into fine grained sandstone with a gradual increase in bioturbation. The top of the sandstones contain abundant trace fossils; mainly *Chondrites* but also *Teichichnus*, *Rhizocorallium* and *Thalassinoides* (Plate 11 and 12A). Diagenetic, calcareous, sandstone nodules up to 0.2m in size are common in some of the sandstones (Plate 12C) and may contain abundant crinoid debris (Plate 12B). The fauna is abundant and well preserved; the following species were obtained.

PLATE 11

PLATE 11. Trace fossils in the Scalpa Sandstone.

A. Teichichnus

B. Rhizocorallium

C. Thalassinoides

Lower Scalpa Sandstone, upper ibex or lower davoei zone, foreshore 1.6km S of South Screapadal (587 425). A and B in situ. C from an ex situ block. Pencil is 15cm long.

PLATE 12

PLATE 12A. Trace fossils. Thalassinoides reworked by Chondrites. Lower Scalpa Sandstone, upper ibex or lower davoei zone. in situ. Foreshore 1.6km S of South Screapadal (587 425). Pencil is 15cm long.

PLATE 12B and C. Diagenetic calcareous sandstone nodules in Lower Scalpa Sandstone, upper ibex or lower davoei zone. Foreshore 1.6km S of South Screapadal (587 425). 12B. Nodule contains abundant crinoid debris. Pencil is 15cm long.

Belemnites	Passaloteuthis apicicurvata
	P. cf. ridgensis (figure 8a)
	Gastrobelus sp. A (figure 8c)
Bivalves	Gryphaea gigantea
	Ostrea sp.
	Pseudopecten aequivalvis
	Chlamys sp.
Brachiopods	Homoeorhynchia capitulata (figure 7b)
Crinoids	Pentacrinus sp.
Lobsters	Glyphea sp. (figure 7a)
Reptiles	Plesiosaurus sp. (plate 13)

These beds were regarded as representing the jamesoni zone of the Pabba Shales by Lee, 1920 (p. 24). The jamesoni zone is exposed along Hallaig Shore in southern Raasay (592 390) where the fauna includes; Uptonia jamesoni, Gastrobelus sp. B, Elliottibelus ex. gr. junceus and E. cf. charmouthensis. The lower margaritatus zone is exposed on the foreshore below Beinn na Leac in southern Raasay (599 368) and yields; Lytoceras gigas, Passaloteuthis apicicurvata, P. tuffleyensis sp. nov. and Hastites clavatus; this fauna is typical of that found in the lower margaritatus zone at Tuffley Hill in Gloucester. The belemnite fauna of the lower Scalpa Sandstone below Druim an Aonaich is of intermediate age and the late ibex to early davoei zone is indicated.

Exposures showing higher parts of the Scalpa Sandstone are numerous but poor. They consist dominantly of fine grained yellow sandstone. Cyclicity may be present in the form of alternating beds of friable sand and calcareous sandstone or doggers. Few fossils were seen in situ but a good fauna can be collected from loose blocks on the foreshore.

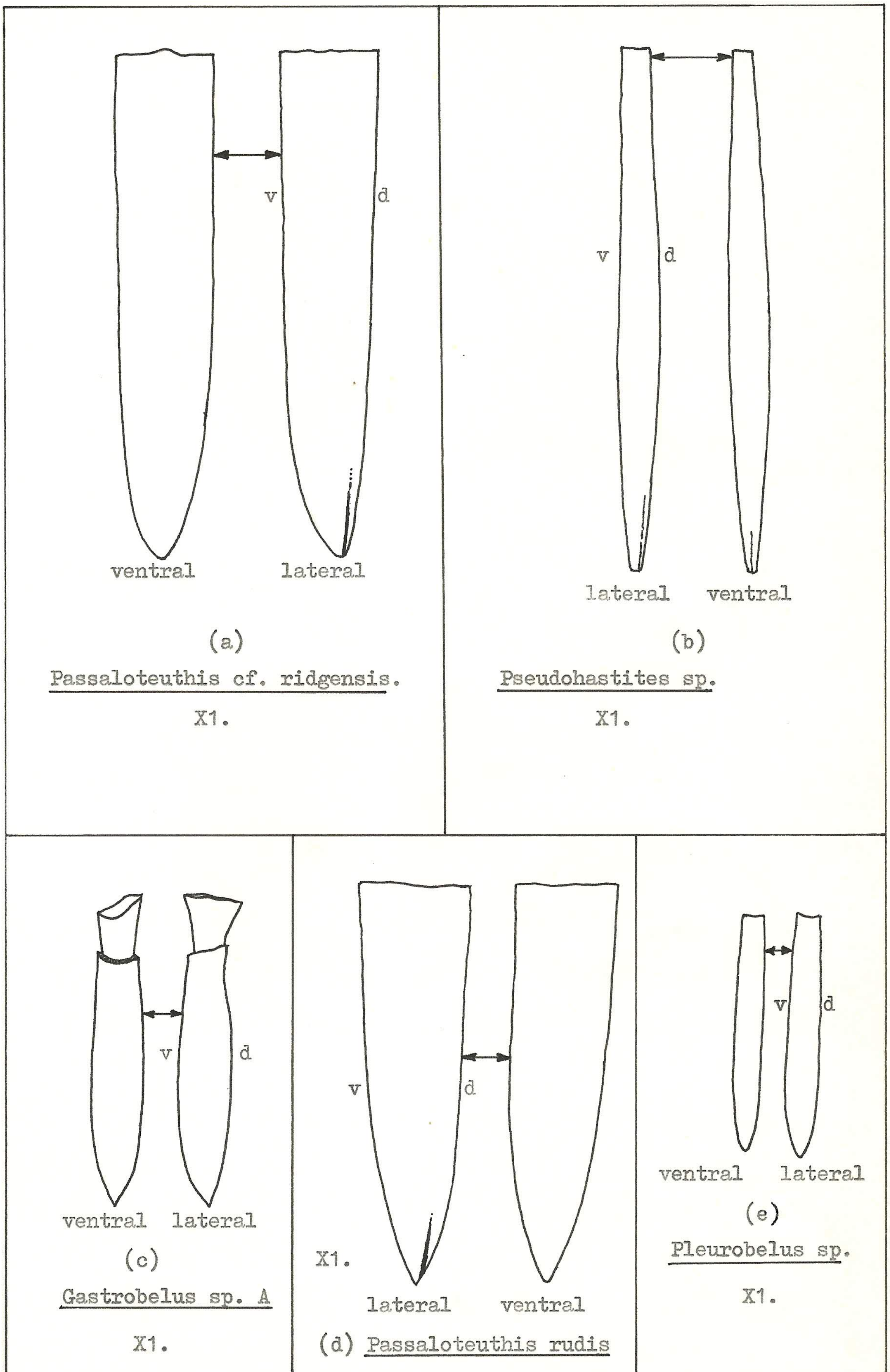


Figure 8. Belemnites from the Scalpa Sandstone. (a) and (c) from the upper ibex or lower davoei zone, foreshore 1.6km south of South Screapadal (587 425). (b), (d) and (e) from the spinatum zone, loose blocks on the foreshore 1 to 2km south of South Screapadal.

PLATE 13

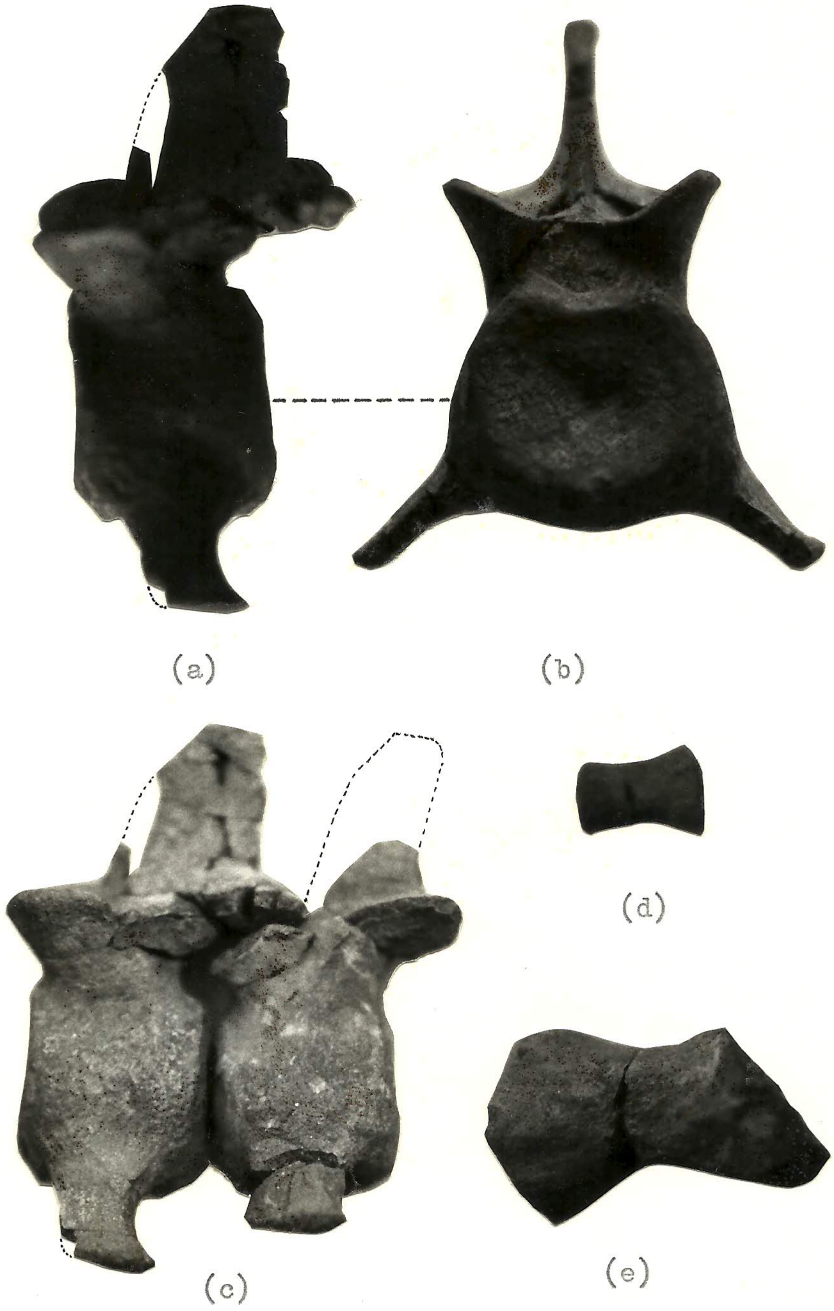


PLATE 13. Plesiosaurus sp.

(a)-(b). Two views of a vertebra. X0.75.

(c). Two vertebrae. X0.6.

(d)-(e). Bones from a paddle. X0.75.

Lower Scalpa Sandstone, upper ibex or lower davoei zone. Foreshore 1.6km S of South Screapadal (587 425).

Ammonites	Pleuroceras sp.
Belemnites	Passaloteuthis rudis (figure 8d)
	Pseudohastites sp. (figure 8b)
	Pleurobelus sp. (figure 8e)
Brachiopods	Tetrarhynchia tetrahedra
	Grandirhynchia grandis
	"Rhynchonella" sp.
Bivalves	Pseudopecten aequivalvis
	Ostrea sp.
Echinoderms	Pentacrinus sp.
	Rhabdocidaris sp.
Bryozoans	ind.

This fauna is entirely of spinatum zone age and no indication of the margaritatus zone were found.

In southern Raasay the Scalpa Sandstone passes up into the tenuicostatum zone (Lee, 1920 p. 25; Howarth, 1956 p. 362) but no evidence of this zone was found in central Raasay.

PORTREE SHALES

There are no exposures of the Portree Shales but loose blocks were found in a small slip below Druim an Aonaich, 1.2km south of South Screapadal (585 430). They consist of medium to dark grey, weakly micaceous shales and siltstones. Ammonites and bivalves are abundant but belemnites are rare.

Ammonites	Harpoceras exaratum	(figure 9d)
	H. elegans	
	Dactylioceras sp.	
	Phylloceras sp.	
Belemnites	Odontobelus tripartitus	(figure 9b)
Bivalves	Astarte subtrigonia	
	Pectinid	

This fauna indicates the exaratum subzone of the falciferum zone.

Loose fragments of Harpoceras falciferum and Hildoceras bifrons were also found in this slip. They are preserved in pale grey limestone and indicate that the Portree Shales extend up to the lower bifrons zone in central Raasay.

RAASAY IRONSTONE.

There are no exposures of the Raasay Ironstone in central Raasay, however loose blocks were found in the slip below Druim an Aonaich (585 430). The Raasay Ironstone consists of dark brown, limonitic ooliths in a matrix of dark grey, micritic limestone. A prolific striatulum subzone fauna is present.

Ammonites	Grammoceras thouarsense	(Plate 14B)
	Grammoceras spp.	
	Pseudolioceras cf. compactile	
	Lytoceras cornucopia	(Plate 14A)
Belemnites	Dactyloteuthis irregularis	(figure 9e)
	D. curtus sp. nov.	(figure 9a)

The belemnite D. curtus is described in Appendix 2.

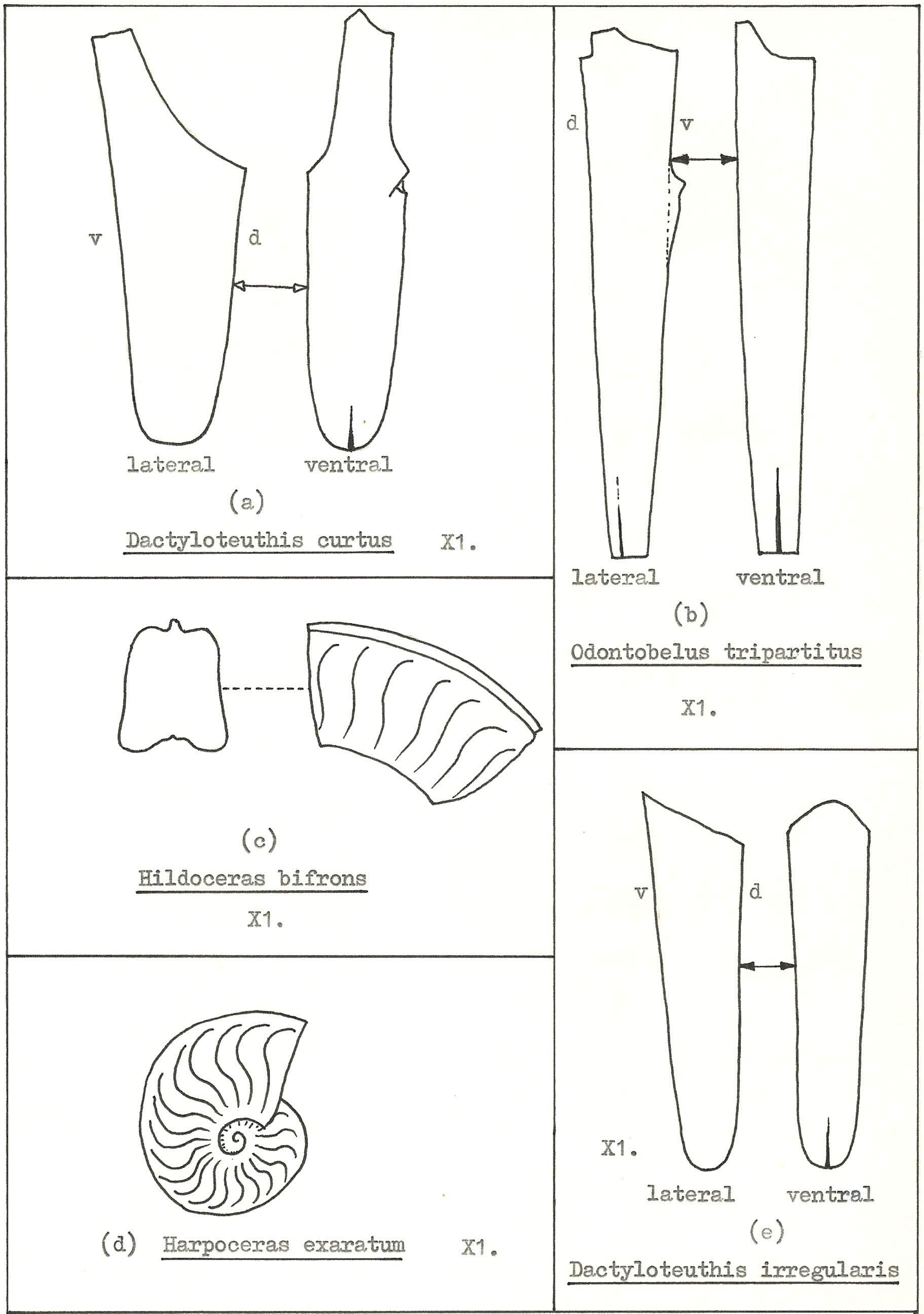


Figure 9. Fossils from the Portree Shales and Raasay Ironstone. (b), (c) and (d) from the Portree Shales. (a) and (e) from the Raasay Ironstone. All from loose blocks found in a slip below Druim an Aonaich, 1.2km south of South Screapadal (585 430).

PLATE 14

(A)

(B)

PLATE 14A and B. Ammonites from the Raasay Ironstone.
(A). *Lytoceras cornucopia*. X0.6.
(B). *Grammoceras thouarsense*. X1.
Striatulum subzone, Toarcian Stage. Loose blocks 1.2km S of South Screapadal (585 430).

PLATE 14C. Planar cross bedded sandstone. Upper Bearreraig Sandstone Formation; small stream that runs over the top of Druim an Aonaich (583 417). Notebook is 25cm high.

This enables a discussion of the correlation of the Toarcian Stage in Raasay and Skye (Table 6). In southern Raasay at Main Mine (568 364) the Raasay Ironstone contains two faunas. At the base a lower bifrons zone fauna of ammonites and belemnites is abundant (personal observation) while the remainder of the ironstone yields only occasional indeterminate belemnites. No evidence of the striatulum subzone is present. In northern Skye the Portree Shales have yielded a good falciferum zone fauna (Anderson and Dunham, 1966 p. 11) and the Raasay Ironstone has yielded "*Dactyloteuthis digitalis*" (Anderson and Dunham, 1966 p. 12) which almost certainly represents a striatulum subzone species. This indicates that the Raasay Ironstone represents a condensed deposit spanning a considerable length of time. Further study may indicate the presence of other zones or subzones.

BEARRERAIG SANDSTONE FORMATION.

The Bearreraig Sandstone Formation has been divided into four members in Raasay (Morton, 1976 p. 25).

Garantiana Clay Member

Raasay Sandstone Member

Beinn na Leac Sandstone Member

Dun Caan Shales Member.

In central Raasay the lower part of this formation is very badly exposed and the relationship between the lower three members is impossible to determine.

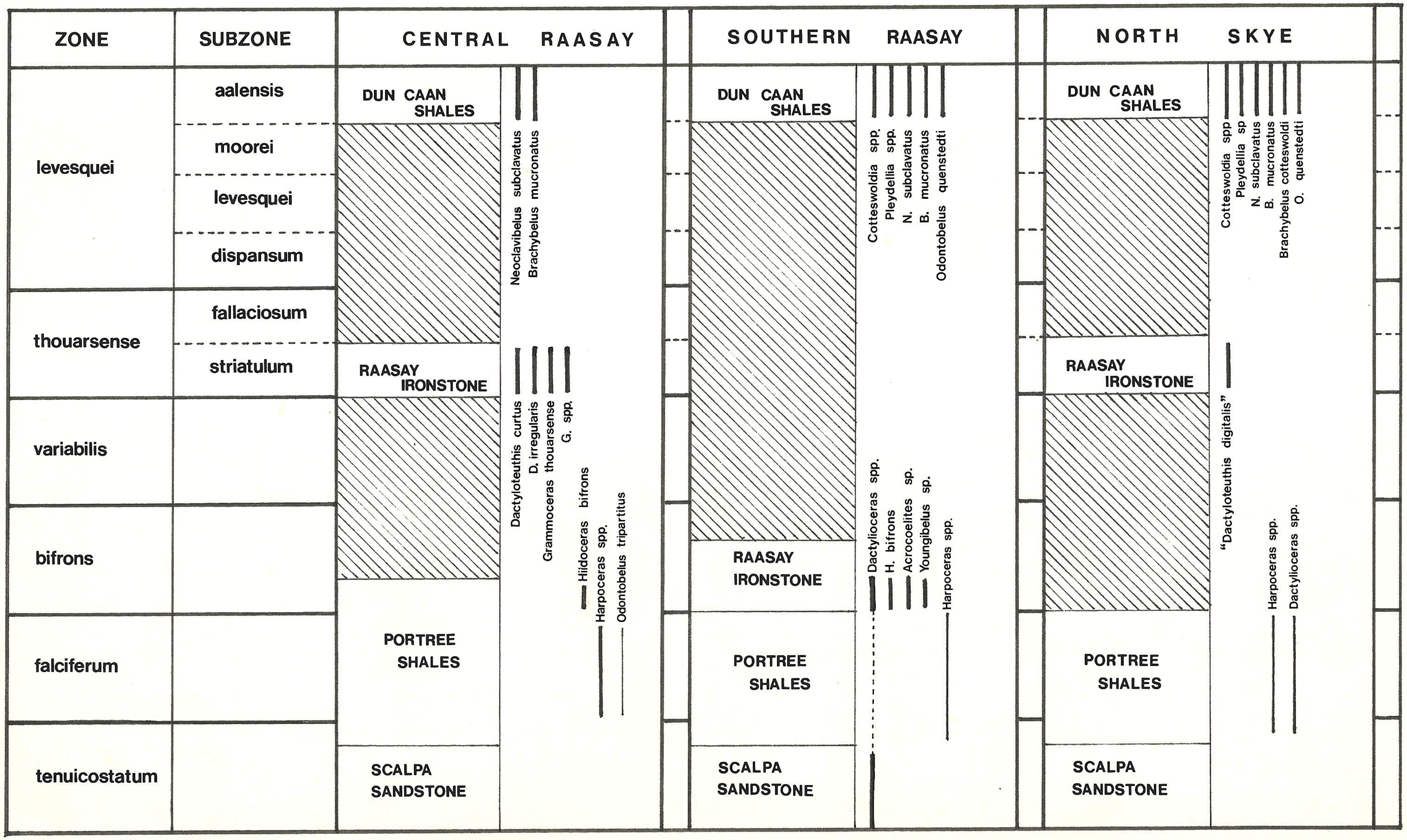


TABLE 6. Toarcian correlation in Raasay and Skye.

Dun Caan Shales Member.

These are represented by dark grey, micaceous siltstones with abundant ammonites and belemnites. The type locality lies in southern Raasay (east of Dun Caan). The Dun Caan Shales are poorly exposed in central Raasay.

In the small, faulted block west of Screapadal (574 439) dark grey, micaceous siltstone is patchily exposed below the Beinn na Leac Sandstone. No fossils were seen.

In the slip below Druim an Aonaich, 1.2km south of South Screapadal (585 430) a loose block of dark grey, micaceous siltstone was found, it yielded;

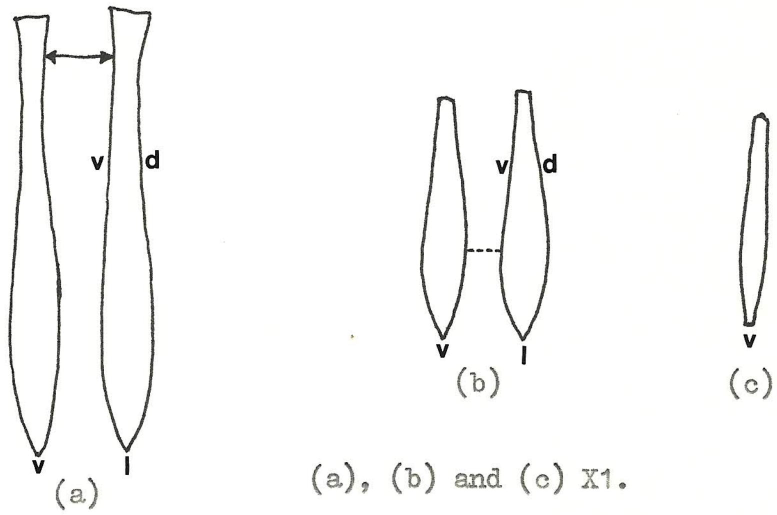
Belemnites Megateuthis sp.
Brachybelus mucronatus sp. nov. (figure 10e)
Neoclavibelus subclavatus

This fauna is typical of the aalensis subzone of the Dun Caan Shales of southern Raasay and northern Skye. At Bearreraig Bay in northern Skye the following cephalopods occur in the aalensis subzone;

Ammonites Pleydellia (Pleydellia) spp.
P. (Cotteswoldia) spp.

Belemnites Odontobelus quenstedti
O. conoides
Megateuthis sp.
Mesoteuthis rhenana
Brachybelus cotteswoldi sp nov.
B. mucronatus sp. nov. (figure 10d)
Neoclavibelus subclavatus (figure 10a)
N. compactus

The belemnites are discussed in Appendix 2.

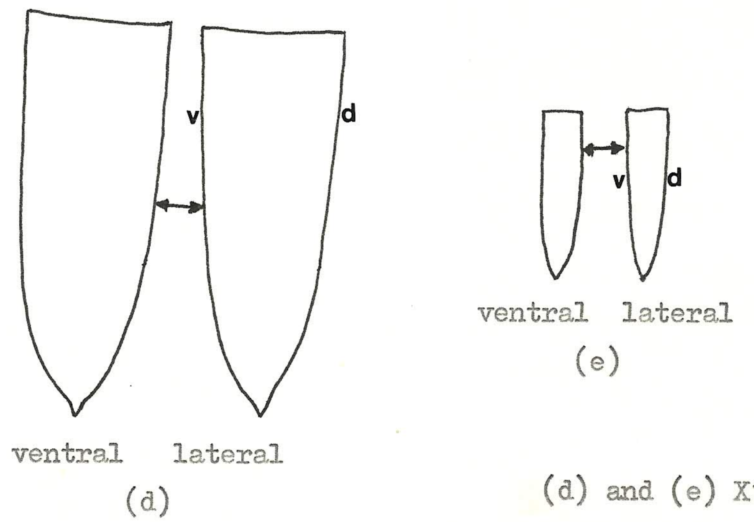


(a), (b) and (c) X1.

(a) Neoclavibels subclavatus. Dun Caan Shales, aalensis subzone; Bearreraig Bay, Skye

(b) N. sp nov. Ollach Sandstone, murchisonae zone; Bearreraig Bay, Skye.

(c) N. sp nov. Raasay Sandstone, ?bed 9; Screapadal (see figure 11a), Raasay.



(d) and (e) X1.

(d) Brachybelus mucronatus sp. nov. Dun Caan Shales, aalensis subzone; Bearreraig Bay, Skye.

(e) B. mucronatus. Dun Caan Shales, ex situ. block in a slip below Druim an Aonaich, 1.2km south of South Screapadal (585 430), Raasay.

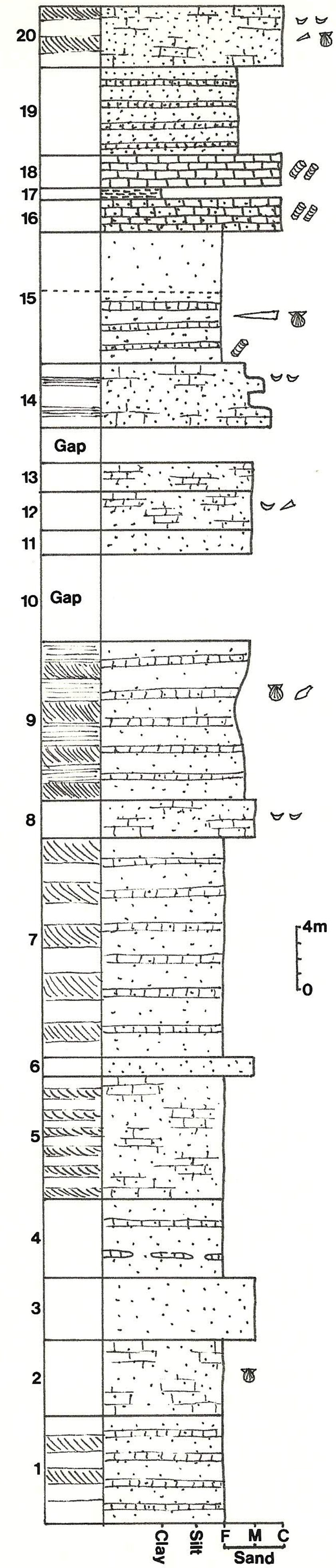
Figure 10. Belemnites from the Bearreraig Sandstone of Raasay and Skye.

Beinn na Leac and Raasay Sandstone Members.

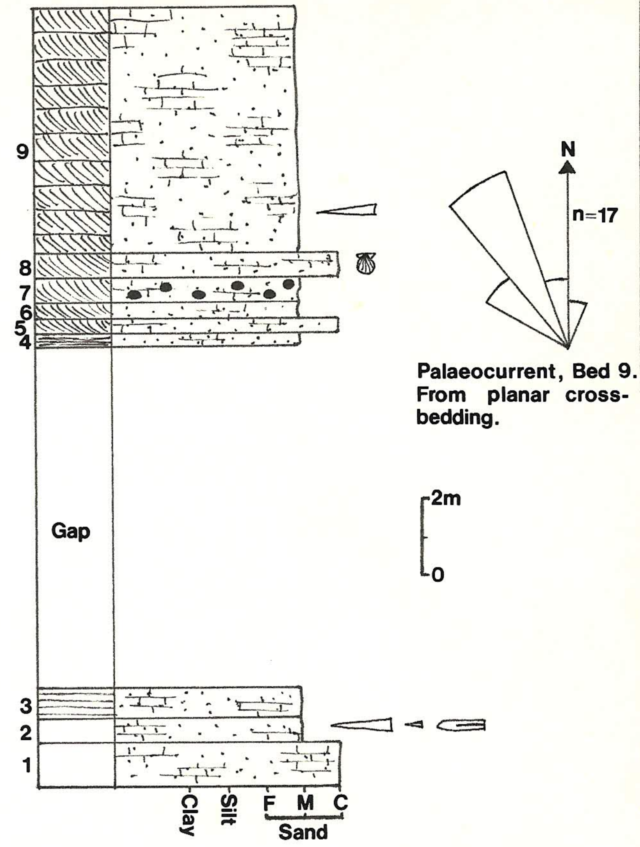
These two members cannot be distinguished in central Raasay because exposures in the lower part of the succession are poor and no ammonites have been found.

The basal part is preserved in the small, faulted block west of Screapadal (574 439). The exposure is very poor and largely overgrown, a single poorly preserved belemnite, possibly an Odontobelus sp. was the only fossil found. This exposure has previously been mapped as part of the Great Estuarine Group (Bradshaw and Fenton, 1982 p. 142) but, the presence of a belemnite clearly indicates it belongs to the Bearreraig Sandstone. This presumably represents the lower part of the Beinn na Leac Sandstone.

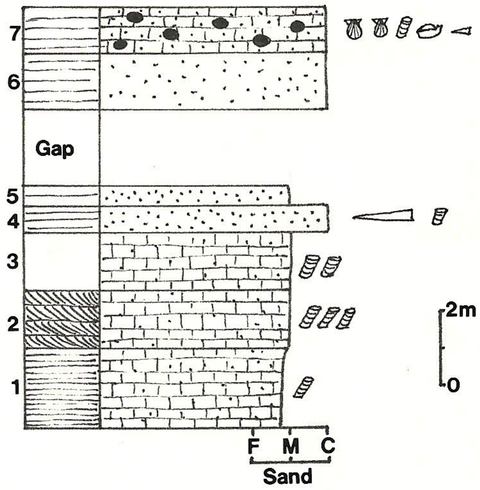
The main part of the Bearreraig Sandstone forms the upper part of the cliffs below Druim an Aonaich. These cliffs are highly unstable and have slipped seaward over the clays and siltstones of the Toarcian. This has produced numerous deep fissures which make the cliff-top very dangerous. The best section through these beds is at the northern end of the cliffs near South Screapadal (579 441). The section is totally within the Raasay Sandstone Member and neither the top or bottom is exposed. A log through the section is shown in figure 11a. The section consists mainly of fine and mediumgrained yellow sandstone often arranged in cycles 1 to 4m thick. These cycles consist of alternating layers of friable sand and calcareous sandstone. Planar cross bedding is developed in about half the sandstone, the remainder is either parallel laminated or massive. Bioclastic material is rare in the lower half of the section but becomes increasingly common towards the top with the development of gritty,



(a) Cliff Section at South Screapadal (579 441).



(b) Cliff Top, Druim an Aonaich (582 420).



(c) Exposures 900m E of Glame (569 429).
The "Raasay Cornbrash".

Figure 11. Logs in the Bearreraig Sandstone Formation of Raasay.

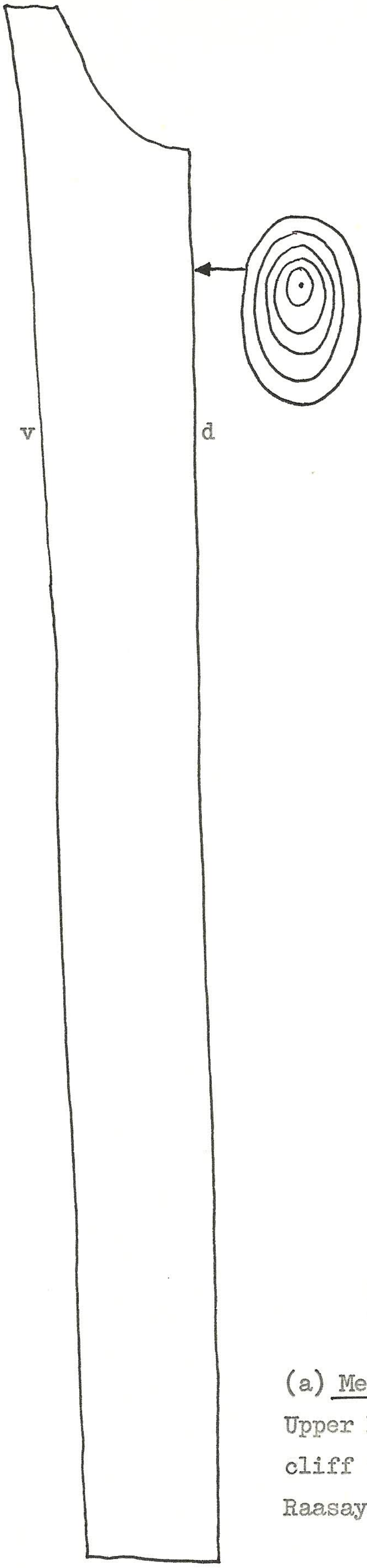
crinoidal limestone layers (beds 16 and 18). A single bed of brownish grey clay is also present (bed 17). Belemnites are the only important biostratigraphical fossils found. A *Neoclavibelus* was found in a loose block thought to have come from bed 9 (figure 10c). *Neoclavibelus* has not previously been recorded above the opalinum zone (Riegraf, 1980 p. 167) but occurs in the murchisonae zone at Bearreraig Bay (figure 10b). The Screapadal specimen represents a new species of mid Lower Bajocian age. *Megateuthis ellipticus* is present in bed 15. At Bearreraig Bay this species occurs in the sauzei and humphriesianum zones and bed 15 therefore, probably belongs to the sauzei zone.

The upper part of the Raasay Sandstone consists dominantly of planar cross bedded sandstones in units 0.5 to 1.5m thick. There are two good exposures. The first is in the banks of the small stream that runs over the top of Druim an Aonaich (582 420). This is shown in figure 11b and in plate 14C. Fossils are common only at certain horizons

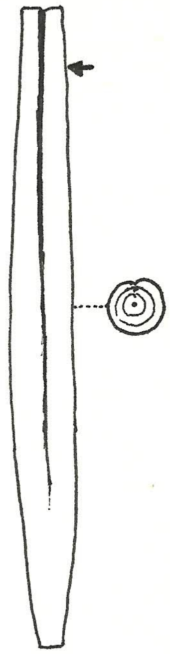
Belemnites	*Megateuthis ellipticus* (figure 12a)
	Belemnopsis cf. anomalus
	Brachybelus sp. (figure 12d)
Bivalves	*Melagrinella sp.*

The palaeocurrent is approximately NNW (determined from planar cross bedding and corrected for tectonic dip).

The second exposure is in the banks around the stream 400m south of Brae (560 413). The succession here consists totally of planar cross bedded sandstones indicating a palaeocurrent towards the N. No fossils were seen.



(a)



(b)

(c)

B. cf. anomalus.
Raasay Sandstone, bed of stream, 600m S of Beinn a Chapuill, Raasay (570 434).

(b) Belemnopsis anomalus.
Rigg Sandstone, humphriesianum zone; Bearreraig Bay, Skye.

(d)

Brachybelus sp.
Same horizon and location as (a).

(a) Megateuthis ellipticus.
Upper Raasay Sandstone (bed 2 of figure 11b), cliff top, Druim an Aonaich (582 420). Raasay.

Figure 12. Belemnites from the Bearreraig Sandstone Formation. All full size.

There are an additional series of small exposures of the Raasay Sandstone in and around the tributaries to Glam Burn. In the bed of the highest tributary, 600m south of Beinn a Chapuill (570 434), brown, medium grained sandstone is exposed with;

Belemnites	Belemnopsis cf. anomalus (figure 12c)
Bivalves	Chlamys sp.
Crinoids	Pentacrinus sp.

This is of similar lithology to bed 20 at Screapadal. In the second tributary 700m east of Glame (567 428), alternating beds of friable and calcareous, yellow sandstone are exposed. These contain common fossils including; Megateuthis ellipticus, Pentacrinus and bivalves. This is of similar lithology to bed 15 at Screapadal. On the higher ground east of this tributary, about 900m east of Glame (569 429), there are several small exposures of gritty, cross bedded, crinoidal limestone and sandstone (figure 11c). These represent the "Cornbrash" of Lee, 1920 (p. 58) but really only represent a crinoidal band in the uppermost part of the Raasay Sandstone (Bradshaw and Fenton, 1982). A good fauna is present;

Ammonites	Garantiana sp.
Belemnites	Megateuthis ellipticus
	Brachybelus sp.
Crinoids	Pentacrinus sp.
Bivalves	Meleagrinella sp.
Brachiopods	ind.
Bryozoans	ind.

This is probably a subfurcatum zone fauna. Bradshaw and Fenton, 1982 (p. 139) introduced the term "Glam Sandstone" for these exposures; the term is rejected herein because,

(i) The name Glame Beds has been used by Selley for part of the Torridonian.

(ii) This is not an abnormal lithology for the Raasay Sandstone and similar lithologies occur elsewhere (beds 16 and 18 at Screapadal).

Garantiana Clay Member.

This member was formerly exposed in the bank of the stream 300m ENE of Brae (563 418) but was not found during this survey. It is represented by pale grey, blocky clay with common ammonites (Lee, 1920; Stevens, 1985). The fauna includes;

Ammonites	*Garantiana filicosta*
	G. baculata
	Strenoceras spp.
Ostracods	*Glyptocythere raasayensis*

GREAT ESTUARINE GROUP

This group has recently been revised by Harris and Hudson, 1980. They divided it into 7 formations, the lower five being present in Raasay. These are as follows;

Duntulm Formation

Valtos Sandstone Formation

Lealt Shale Formation

Elgol Sandstone Formation

Cullaidh Shale Formation

The group is on the whole non-marine but at certain horizons some marine fossils are present. This indicates that there was a marine connection and that at times near marine conditions were established.

Cullaidh Shale Formation (Basal Oil Shale).

In Raasay this formation has a thickness of about 7.5m and shows a transition from fully marine conditions at the base to non-marine conditions at the top.

The best exposure is in the bed and banks of the stream 400m ENE of Brae (565 418), figure 13b. It consists of dark grey, micaceous siltstone with occasional beds of grey, fine grained sandstone. Carbonized plant fragments occur throughout and bioturbation increases towards the top of the unit. The transition into the overlying Elgol Sandstone Formation is gradational. At the base of the Cullaidh Shale there is a 1m thick band that yields abundant fossils;

Bivalves	Quenstedtia cf. bathonica	(figure 14a).
Crinoids	?Isocrinus sp.	
Ostracods	Glyptocythere cf. scitula	(figure 14b).
Fish Scales.		

This fauna was first recognized by Forsyth, 1960 (p. 274) who termed the bed the "Quenstedtia Shale". Following Hudson, 1962 (p. 147) I consider this horizon represents the basal part of the Cullaidh Shale. Forsyth, 1960 (p. 274) recorded the ostracod Bairdia which is almost certainly an incorrectly identified Glyptocythere.

The top of the Cullaidh Shale is also seen in the small stream that runs over the top of Druim an Aonaich (581 420), see figure 13a. Other exposures are poor; it is seen beneath the granophyre sill in the bank of Allt a Bhraghad at Brae (562 416) and also, in a bank 1.3km south of Beinn a Chapuill (570 426).

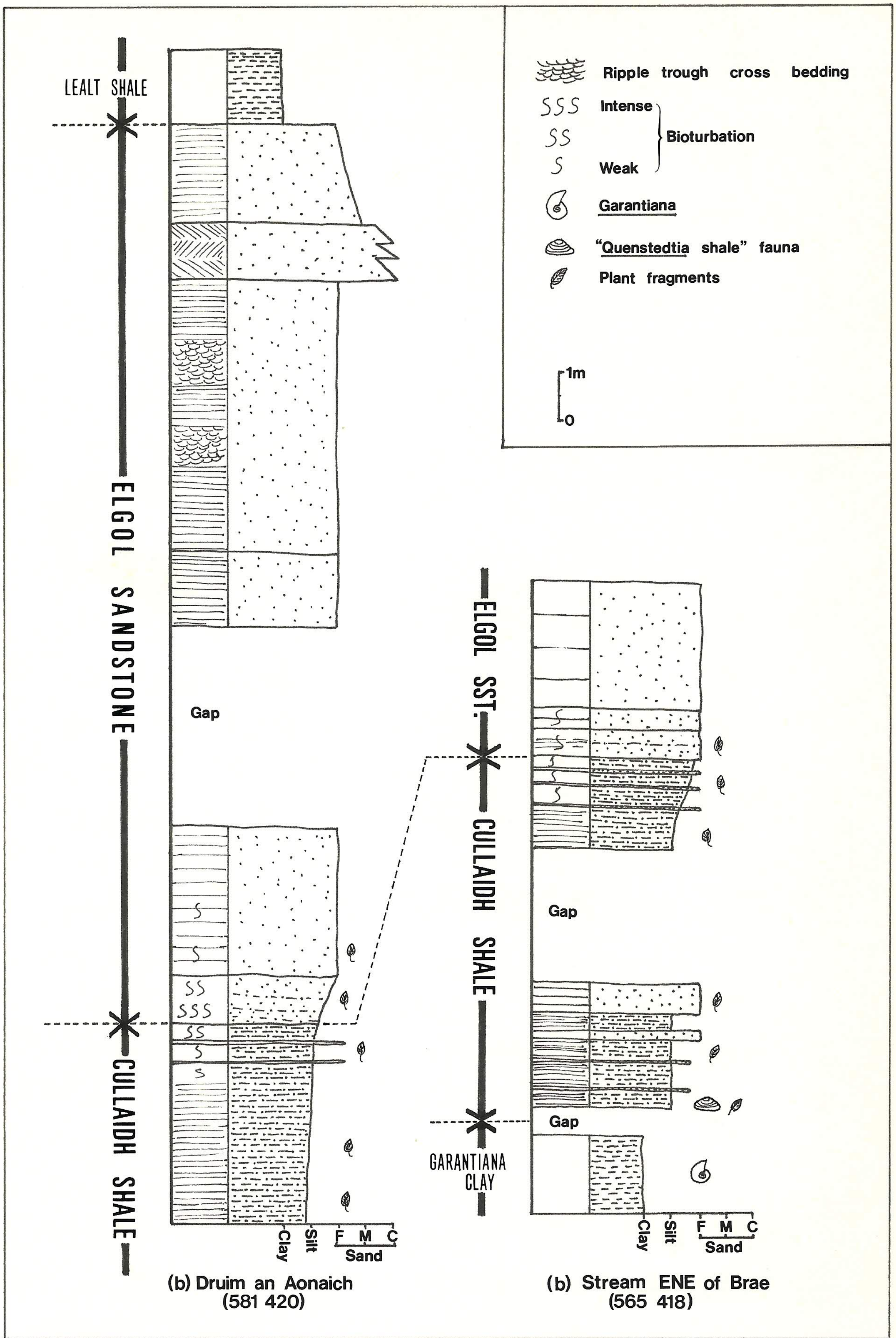
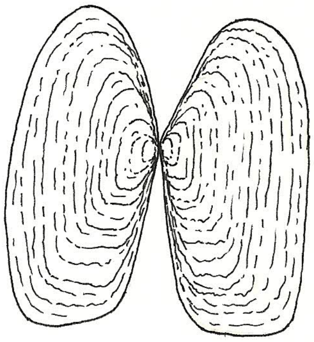
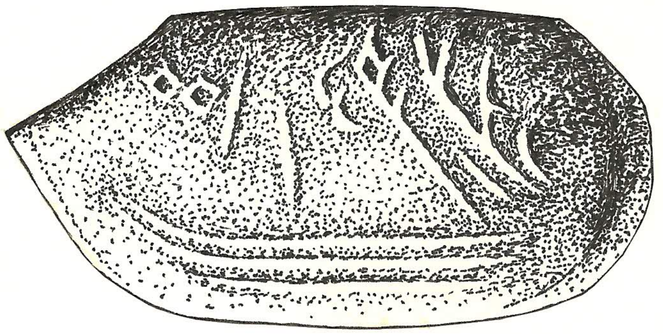


Figure 13. Logs through the Elgol Sandstone and Cullaidh Shale in central Raasay.



(a)

Quenstedtia cf. bathonica (Morris and Lycett). "Quenstedtia shale", lower Cullaidh Shale Formation. Stream bank 300m ENE of Brae (565 418). X2.



(b)

Glyptocythere cf. scitula Bate. This species lacks the reticulation of G. raasayensis Stevens from the Garantiana Clay of Raasay and shows closer similarity to G. scitula from the Scarborough Formation of Yorkshire. "Quenstedtia shale", lower Cullaidh Shale Formation. Stream bank 300m ENE of Brae (565 418). X60.

Figure 14. Fossils from the lower Cullaidh Formation ("Quenstedtia Shale") of Raasay.

Elgol Sandstone Formation (White Sandstone).

This formation is well exposed in Raasay and has a thickness of about 18m. The best exposure is in the banks of the stream that runs over the top of Druim an Aonaich (581 420), see figure 13a. The basal part consists of silty, bioturbated, fine grained sandstones which contain abundant carbonized plant fragments. The middle part consists of clean, fine grained sandstone with parallel laminations or trough cross ripple laminations (plate 15A). The upper part is represented by a fining upwards sequence with wide fluctuations in palaeocurrent direction although, the dominant direction is north (planar cross bedding corrected for tectonic dip). This formation is interpreted as a coarsening upwards delta front sequence cut by a channel sandstone unit at the top.

The base of the formation is also well seen in the banks of the stream 400m ENE of Brae (565 418), see figure 13b. Other exposures are in the base of the waterfall at Glac Dhorcha (564 416) and in a bank 1.2km south of Beinn a Chapuill (570 427).

Lealt Shale Formation.

This is the most poorly exposed part of the Great Estuarine Group. The only exposures seen are in the bed of the stream that runs over the top of Druim an Aonaich (580 419). A few small patches of soft, grey shales are seen in the bed of the stream below an argillaceous limestone band. This limestone band is about 15m above the Elgol Sandstone and is stromatolitic. This band occurs across the outcrop of the Lealt Shale from Eigg to northern Skye and is used to divide the Shale into two members; the Kildonnan

PLATE 15

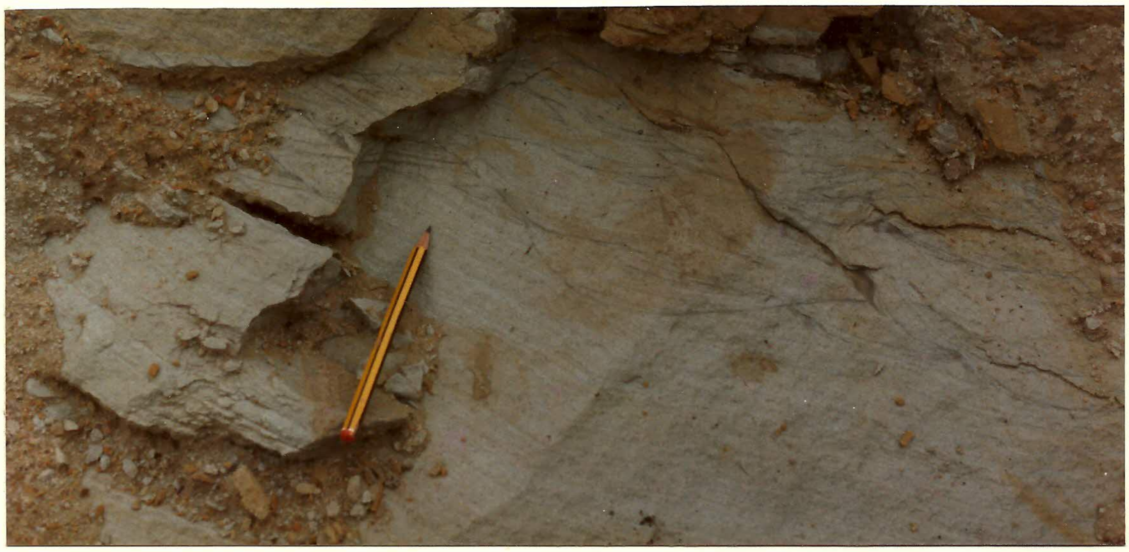


PLATE 15A. Ripple trough cross bedding in the middle part of the Elgol Sandstone Formation. Small stream that runs over the top of Druim an Aonaich (581 420). Pencil is 15cm long.

PLATE 15B. Orange limonitic band in grey shales of the upper Valtos Sandstone Formation. Note contact with dolerite sill with a 2cm thickness of baked shale. Small cliff 1.8km ESE of Glame (576 422). Pencil is 15cm long.

Member below and the Lonfearn Member above. The thickness of the Kildonnan Member can be estimated at 15m in Raasay and this compares well with a thickness of 18m in the Lealt-Lonfearn district of Skye (Harris and Hudson, 1980 p. 239). No fossils were found in this member.

The Lonfearn Member is unexposed in central Raasay except for a band of beef about 1m above the stromatolitic bed. The thickness of this member cannot be determined.

Valtos Sandstone Formation (Concretionary Sandstone Series).

This formation is moderately well exposed in central Raasay. It consists of alternating layers of grey shales, grey siltstones, fine to medium grained yellow sandstones and occasional limestones. A few of the sandstones contain calcareous concretions upto 0.3m in diameter and these gave the unit its old name "Concretionary Sandstone Series". The base of the unit is defined as the appearance of silty shales with monotypic Neomiodon beds (Harris and Hudson, 1980 p. 240) but the base is not seen in Raasay.

The best and thickest exposure is seen in a vertical cliff section 1.3km SW of Screapadal (578 430). A thickness of about 38m is exposed, see figure 15. Neomiodon brycei (figure 16a) is abundant and occurs throughout often in monotypic shell beds (plate 16A). Gastropods occur in some beds; Viviparus (figures 16b and f) in beds 28 and 31 and Cylindrobullina (figure 16e) in bed 23. Indeterminate trace fossils occur on the tops of some sandstone beds and symmetrical ripples were seen on a fallen block.

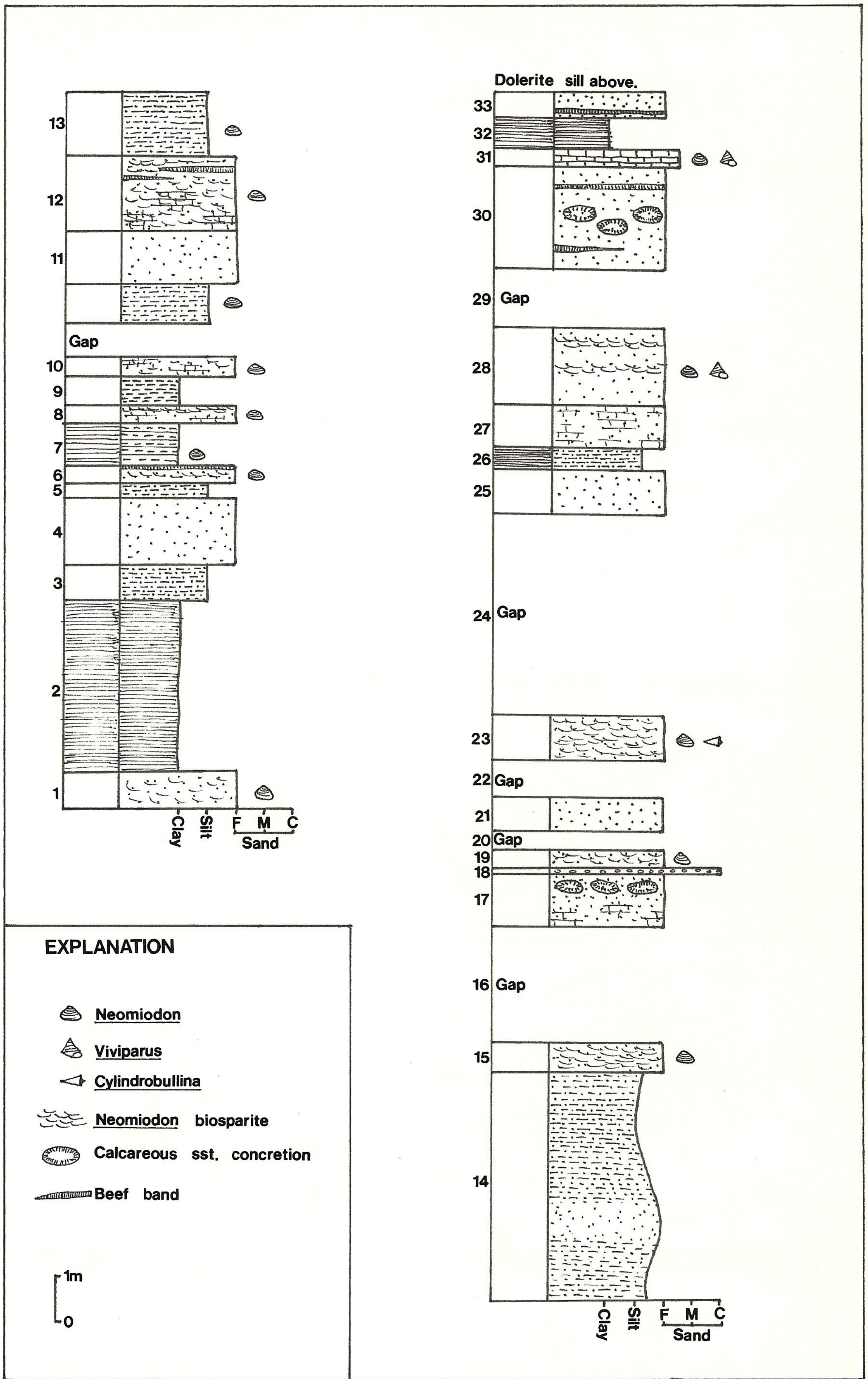
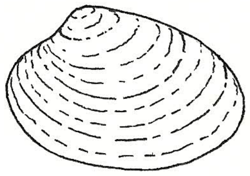


Figure 15. Log through part of the Valtos Sandstone Formation. Vertical cliff section, 1.3km SW of Screapadal (578 430).

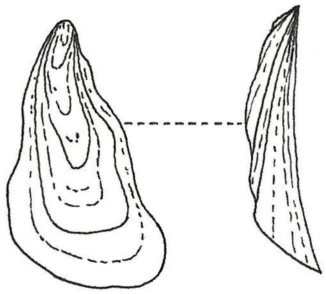


(a)

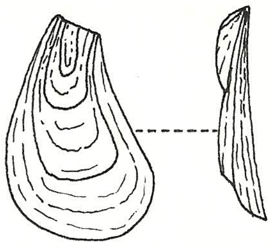
Neomiodon brycei (Tate). X2.
Valtos Sandstone Formation.

(b)

Viviparus cf. bithnyoides (Yen).
X2. Valtos Sandstone Formation.

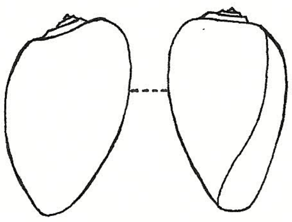


(c) Left valve.



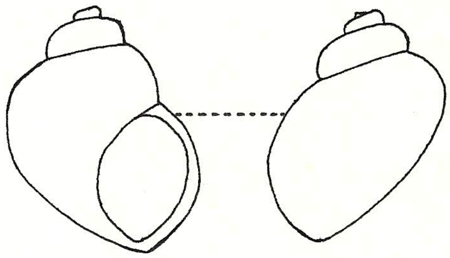
(d) Left valve.

Praeexogyre hebridica (Forbes). Two different specimens.
X1. Duntulm Formation.



(e)

Cylindrobullina inermis (Tate).
X2. Valtos Sandstone
Formation.



(f)

Viviparus scoticus (Tate).
X1. Valtos Sandstone
Formation.

Figure 16. Fossils from the Valtos Sandstone Formation and the Duntulm Formation. (a), (b) and (e) from a shell band, 2.1km SE of Glame (577 419). (c) and (d) from a small exposure 1.8km ESE of Brae (575 411). (f) from bed 31, cliff section, 1.3km SW of Screapadal (578 430).

PLATE 16

PLATE 16A. Neomiodon biosparite. Valtos Sandstone Formation. The limestone is composed entirely of shells belonging to Neomiodon brycei. Cliff section 1.2km SE of Beinn a Chapuill (578 430). X1.

PLATE 16B. Cylindrobullina-Neomiodon rich calcareous sandstone. Valtos Sandstone Formation. Fauna includes; abundant Cylindrobullina inermis and Neomiodon brycei with occasional Viviparus cf. bithnyoides. Small exposure 2.1km SE of Glame (577 419). X1.

These beds can be traced towards the south from this exposure and many of the sandstones form small features. At one exposure 2.1km SE of Glame (577 419) a shell bed with abundant fossils was found, it yielded;

Bivalves   Neomiodon brycei (abundant)

Gastropods   Cylindrobullina inermis (abundant)

Viviparus cf. bithnyoides (uncommon).

A piece of this bed is shown in plate 16B.

The higher part of the Valtos Sandstone is exposed in a small cliff section 1.8km ESE of Glame (576 422). About 5m of grey shales including a thin orange limonitic clay band are exposed beneath a dolerite sill, see plate 15B.

The Valtos Sandstone is interpreted as a lagoonal deposit, because of the similarity between the monotypic Neomiodon beds and modern monotypic Tellina shell banks in tropical lagoons (Barbuda, Lesser Antilles).

Duntulm Formation (Lower Ostrea Beds).

The base of the formation is defined as the first appearance of Praeexogyra hebridica (Harris and Hudson, 1980 p. 243). On Skye it consists of alternating beds of limestone and shales with abundant P. hebridica and occasional layers with marine bivalves, gastropods and rhynchonellids. The beds were believed to be present on Raasay by Woodward, 1914 but were not recognized by Lee, 1920. Bradshaw and Fenton, 1982 (p. 141) found boulders containing

P. hebridica on the higher reaches of the second tributary to Allt a Bhraghad (576 416). The Duntulm Formation occurs in situ in a series of small exposures 1.8km ESE of Brae (575 411). It consists of a dark grey micritic limestone packed full of P. hebridica (figure 16c and d). This is identical to the boulders found in the tributary to Allt a Bhraghad. No other fossils were seen.

To the west of these exposures a few patches of yellow sands (1.2km SE of Glame - 570 420) and grey shales (1.1km E of Brae - 572 417 and 0.4km ESE of Glac Dhorcha - 568 414) are exposed. No faunas were recovered but from the dip of the Jurassic and assuming no faulting these would appear to be part of the Duntulm Formation.

6. THE BRECCIATED TORRIDONIAN

The Brecciated Torridonian consists of five separate bodies, circular or elliptical in plan view that lie in a straight line trending NW-SE. Three of these bodies are large with diameters between 50 and 100m and are well exposed. The other two are small with diameters between 5 and 10m and are poorly exposed. Figure 17 shows the locations and names used for these deposits. These represent the most intriguing deposits found on Raasay as their mode of formation is unknown. The descriptions will concentrate on the three well exposed larger bodies.

DESCRIPTION OF DEPOSITS

The Brochel Castle Breccia and the Loch an Uachdair Breccia are subcylindrical bodies whose bases are not visible. The walls of these bodies are vertical and show no signs of deformation. The deposits consist of unsorted clast support breccias. The clasts are angular and composed entirely of Torridonian material. No Lewisian clasts are present. The breccias are cemented by calcite rhombs up to 10cm in size, see plate 17. No bedding or grading is present. There are a few post-depositional fissures cutting the breccias.

The Hillside Breccia is very well exposed and is by far the most important in understanding these deposits. This rests on the Lewisian and does not appear to penetrate it. The clasts are composed entirely of Torridonian material and no Lewisian clasts are present. Close to the western edge, the clasts are larger (up to 4m in size) and

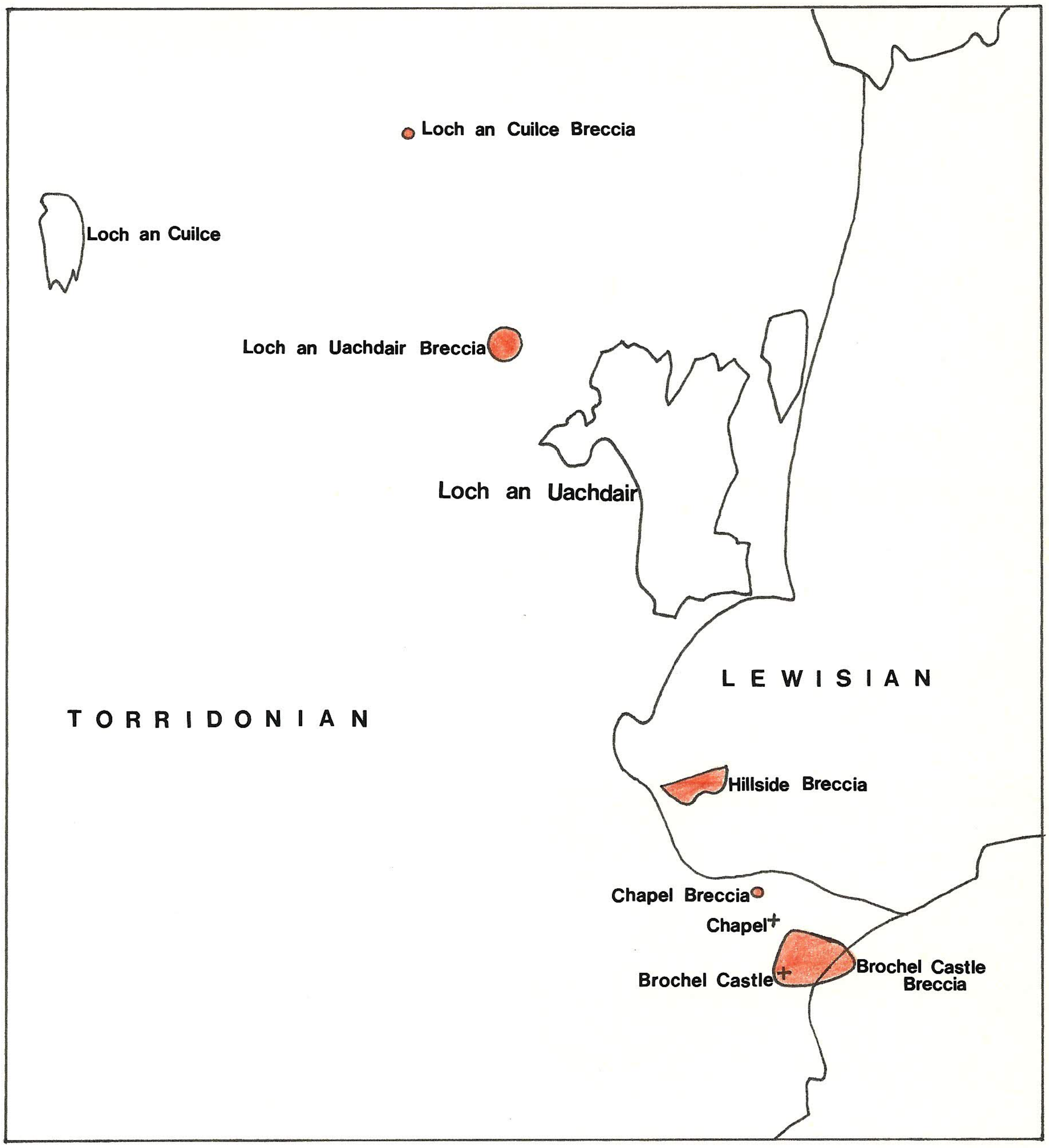


Figure 17. Sketch map showing the location and names used in the text for the Brecciated Torridonian deposits of Raasay.

PLATE 17

PLATE 17A. The Brochel Castle Breccia. Two "stacks" with the remains of Brochel Castle on the top of the closest one. Note the Hillside Breccia on the horizon. Brochel Castle (585 463).

PLATE 17B. Loch an Uachdair Breccia. Close-up showing angular clasts cemented by rhombs of white calcite. Clast support fabric. 200m NW of Loch an Uachdair (580 472). Pencil is 15cm long.

clearly represent material fallen into a hole (plate 18). As we move away from the edge the brecciation of the clasts increases and a kind of bedding is developed. This bedding represente original alternating sandstone and siltstone beds that have been brecciated to produce alternating beds of sandstone clasts and siltstone clasts. This is consistent with larger clasts breaking up as they fell into a preexisting hole. Above a line of sandstone clasts (plate 18) the breccia is unordered and similar to the deposits found in the Brochel Castle and Loch an Uachdair Breccias. The cement in the western part of the Hillside Breccia consists of calcite rhombs while elsewhere it is either uncemented or has a sandy calcite cement. A recent dripstone cement has formed beneath an overhang by solution and redeposition of calcite.

The clasts from the breccias consist of very well cemented Torridonian sandstone and siltstone. It is therefore clear that the breccias were formed a long time after the deposition of the Torridonian.

POSSIBLE ORIGINS

1. Volcanic necks. The total lack of volcanic clasts indicates that these are not volcanic necks.

2. Volcanic gases. In situ brecciation of sediments by upward movement of volcanic gases is rejected because (a) we would expect Lewisian clasts to be present, and (b) the depositional structures in the Hillside Breccia are wrong.

PLATE 18

PLATE 18A. Hillside Breccia sitting totally on the Lewisian. The Lewisian is visible in the ledge at the bottom of the photograph and at the top on the left. 400m NNW of Brochel Castle (583 466).

PLATE 18B. Enlargement of above. Note the line of angular sandstone clasts midway up above which the breccia is totally unsorted. Below this line there are large blocks on the left which gradually become more brecciated towards the right. The nature of this brecciation and the unsorted deposits above indicate the infil of a preexisting hole.

3. Fault related breccias. There are no indications of the development of faults large enough for the formation of these deposits.

4. Collapsed caves. It is difficult to envisage the formation of a series of caves in a silaceous sandstone sequence, however I feel that some form of collapse structure is the most likely origin.

7. QUATERNARY GLACIATION

The evidence of Quaternary glaciation in Raasay is provided by boulder clay, glacial striae and glacial erratics.

BOULDER CLAY.

An extensive area of boulder clay extends from the higher reaches of Allt na Glaic Duirche northwards towards Glame where it passes beneath the peat cover. Exposures occur in Glam Burn 200m east of Glame (562 428), in the ditch on the east side of the road leading south from Glame (562 425) and in the second tributary to Allt a Bhraghad 400m north-northeast of Brae (564 418). The boulder clay is a dark grey clay with numerous clasts in a clast support fabric. The clasts include; dolerite, granophyre, Jurassic sandstone, Torridonian sandstone and Lewisian gneiss.

Another area of boulder clay is probably present around North Screapadal (580 443) where there is a marked feature on the edge of some boggy ground. Bradshaw and Fenton, 1982 (p. 142) incorrectly thought that the boggy ground represented the Broadford Beds. Torridonian sandstone is exposed in the northern banks of An Leth-allt indicating that the Holoman-Screapadal Fault runs along An Leth-allt and not north of North Screapadal as indicated by Bradshaw and Fenton. The Screapadal valley is therefore probably a glacial valley aligned along the Holoman Screapadal Fault.

A small patch of boulder clay is also visible in the banks of Glam

Burn 1.3km northeast of Glame (571 434).

GLACIAL STRIAE.

On a few polished surfaces of the Torridonian a few glacial striae may be found, eg. beside the road 800m west-southwest of Brochel (577 461). These indicate ice movement towards the southeast or northwest.

GLACIAL ERRATICS.

There are numerous glacial erratics on Raasay mainly composed of Torridonian sandstone, dolerite and granophyre. 600m northwest of Brochel Castle there are two large glacial erratics, see plate 19.

80

PLATE 19

PLATE 19. Erratic boulders resting on the Torridonian, 600m NW of Brochel Castle (581 468). The nearest erratic is composed of soft yellow Jurassic sandstone, the other erratic of Torridonian sandstone. The nearest erratic is about 2m across.

PLATE 19

PLATE 19. Erratic boulders resting on the Torridonian, 600m NW of Brochel Castle (581 468). The nearest erratic is composed of soft yellow Jurassic sandstone, the other erratic of Torridonian sandstone. The nearest erratic is about 2m across.

8. IGNEOUS ROCKS (TERTIARY)

Igneous rocks are represented on Raasay by dolerite dykes, dolerite sills and a granophyre sill. There are no extrusive igneous rocks although they have been previously recorded in error. For instance, Bradshaw and Fenton, 1982 (p. 142) incorrectly identified the dolerite sills across the top of Raasay as plateau basalts.

DOLERITE SILLS

A large number of dolerite sills have been intruded into the Jurassic but because of the poor exposure they cannot be mapped in detail. The lowest sills, 10 to 20cm thick, are intruded into the Cullaidh Shale Formation and are exposed in the small stream that runs over the top of Druim an Aonaich (581 420). Higher sills are thicker (up to 20m thick) but are very difficult to map. The best exposures are found around the small valley 1.7km east-southeast of Brae (577 412) where four separate sills have been intruded into the Valtos Sandstone Formation. Many of the large areas of dolerite also probably represent more than one sill but are too poorly exposed to tell. The sills consist of dolerite with variable proportions of olivine present. Some layers contain abundant amygdales composed of fibrous zeolites and occasionally analcite. The amygdales are a variety of shapes and indicate that the sills were originally horizontal (figure 18a and b). Alternating amygdaloidal and non-amygdaloidal layers between 0.3 to 3.0m thick are present in some sills and represent either changing

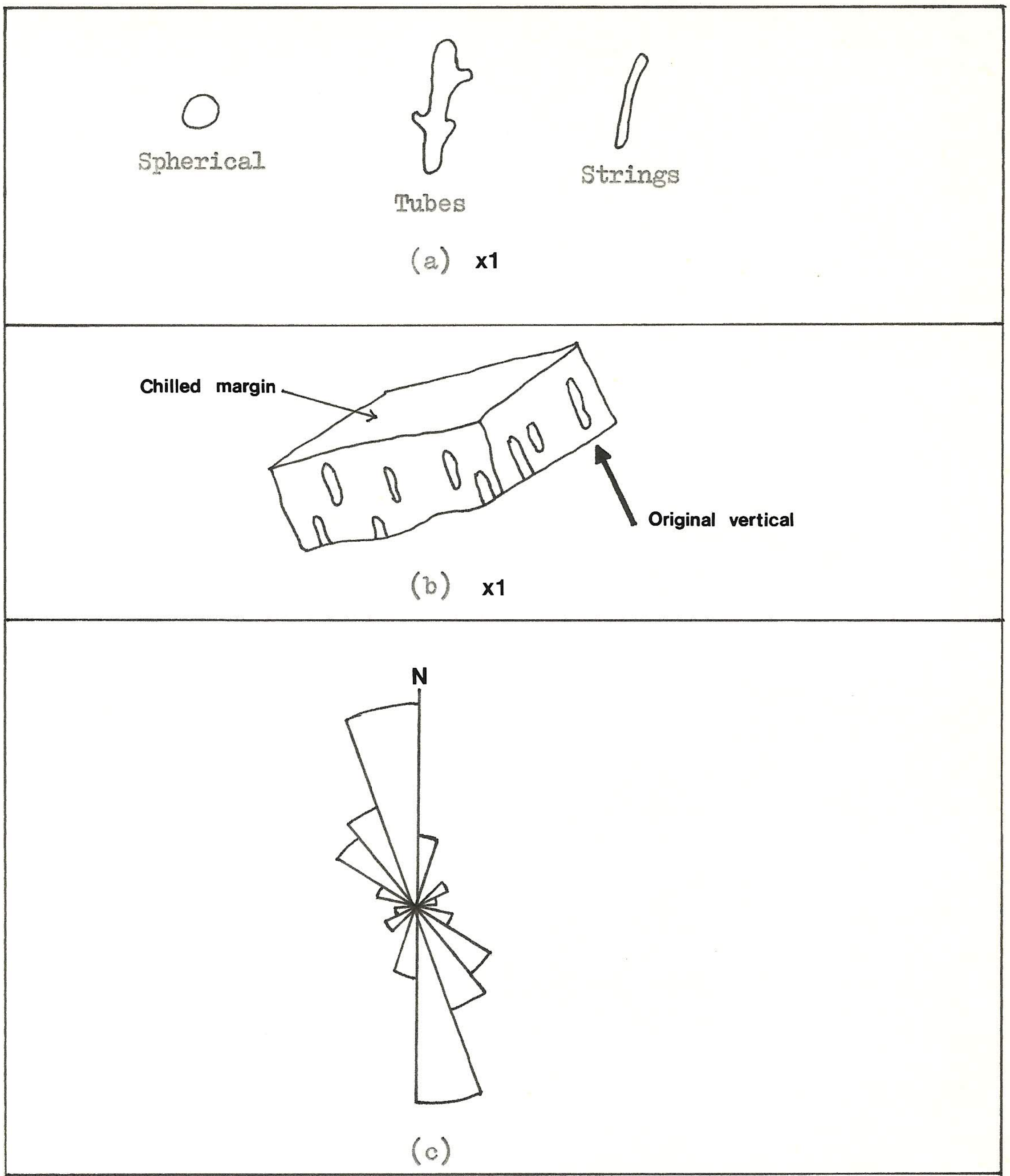


Figure 18. (a) Amygdale shapes in dolerite sill. The elongate amygdales were formed by buoyant movement of the less dense zeolites within the dolerite while the whole lot was still molten. Small gorge 1km E of Brae (572 417).
(b) Amygdale strings in the chilled margin of a dolerite sill. This indicates that the sills have subsequently been tilted and were originally horizontal. Small exposure 2km ESE of Brae (579 412).
(c) Rose diagram showing the trends of 38 dolerite dykes in central Raasay. A clear NNW-SSE trend can be seen.

conditions during crystallization or composite sills. Chilled margins and thin baked shale contacts are occasionally seen and columnar jointing may be present.

GRANOPHYRE SILL

A thick granophyre sill, at least 20m thick, is well exposed over much of Raasay. Only a small part of this sill is present in the area surveyed. The sill is bounded to the east by the Central Raasay Fault and to the west by the small fault that runs along the road. It was intruded into the Cullaidh Shale to the west, and the Elgol Sandstone to the east, of the small fault running along Allt a Bhraghad. This suggests that the fault existed prior to the intrusion of the sill. The granophyre consists of small quartz and feldspar phenocrysts up to 5mm in size with a fine grained ground mass. There are few mafics present.

DOLERITE DYKES

Small dolerite dykes up to 3m wide are fairly common in central Raasay but are not as abundant as in southern Raasay. They have a predominant NNW-SSE trend (figure 18c). The dykes are composed of dolerite with a variable amount of olivine. Many of the dykes contain amygdales of fibrous zeolites aligned in bands parallel to the dyke edges (plate 20A). Phenocrysts of plagioclase up to 1cm in size are occasionally present. Chilled margins are ubiquitous and columnar jointing is usually well developed (plate 20B). Many of the dykes have induced a cleavage into the Torridonian siltstones and sandstones adjacent to their edges. This cleavage is well seen adjacent to the dykes on the foreshore 200m southeast of Brochel Castle (586 462). The dykes are very prone to weathering

PLATE 20

PLATE 20A. Amygdaloidal dolerite dyke showing chilled margin on right. Note bands of amygdales composed of fibrous zeolites. Foreshore 300m S of Brochel Castle (585 460). Pencil is 15cm long.

PLATE 20B. Columnar jointing in a dolerite dyke intruded into the Lewisian. 500m ENE of Brochel Castle (589 464). Pencil is 15cm long.

and do not form marked features. They are consequently difficult to trace.

9. STRUCTURE

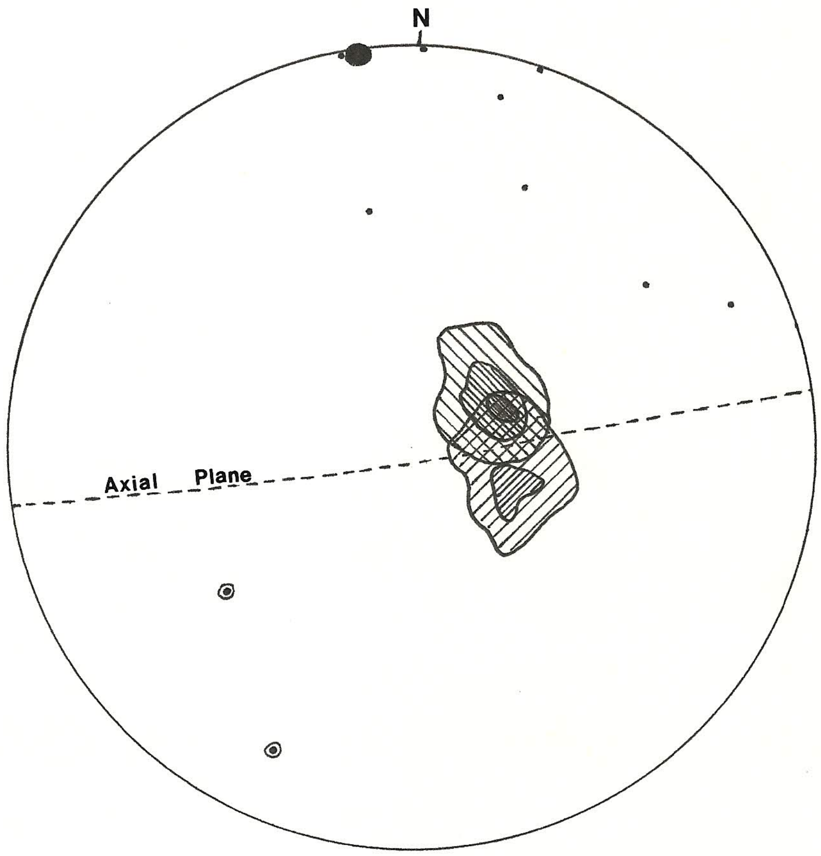
In central Raasay the Torridonian has been affected by gentle folding and a number of faults are present in the Jurassic and the Torridonian. During the late Tertiary the whole area was tilted gently to the west. The post-Lewisian geological history of central Raasay is summarized in table 7.

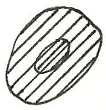
TORRIDONIAN STRUCTURE.

The Torridonian has been very gently folded into a large, upright, very open anticline with a subhorizontal east-west axis. A stereogram is shown in figure 19. This is probably a Caledonian fold. Reverse faults with throws less than 20m are quite common in the Torridonian, particularly along the coast south of Brochel Castle. These faults downthrow to the north and strike predominantly east-west; they are probably associated with the folding.

FAULTS.

Two major faults are named herein, the Holoman-Screapadal Fault and the Central Raasay Fault. The Holoman-Screapadal Fault throws the Jurassic against the Torridonian. It has an almost straight coarse suggesting the fault plane is vertical and downthrows to the south by at least 1000m. The steepening and rotation of the dips in the Torridonian and the apparent curvature of the Jurassic strata indicate sinistral wrench movement. No dykes can be traced across the fault so that the relationship between faulting and dyke




Contoured poles to bedding from northern limb of anticline.


Contoured poles to bedding from southern limb of anticline.

Poles to fault planes on southern limb of anticline.

Poles to fault planes on northern limb of anticline.

Projected pole to axial plane of anticline.

FIGURE 19. Stereogram of anticlinal folding in the Torridonian of Raasay.

AGE [ERA or PERIOD]		EVENTS
QUATERNARY	11	HOLOCENE. Formation of peat.
	10	PLEISTOCENE. Glaciation with the formation of glacial striae and the deposition of boulder clay and erratics.
TERTIARY	9	Normal Faulting and tilting of area towards the west.
	8	Extensive Erosion.
	7	Intrusion of extensive dolerite sills and dykes and granophyre sill.
JURASSIC	6	Deposition of marine sediments followed by fresh or brackish water sediments.
PALAEOZOIC	5	Extensive Erosion.
	4	?Caledonian Orogeny. Formation of gentle E-W anticline and reverse faults in the Torridonian.
PRECAMBRIAN	3	TORRIDONIAN. Deposition of lacustrine siltstones followed by extensive braided stream, red sandstones.
	2	Uplift and extensive erosion exposing basement.
	1	LEWISIAN. Evolution of the Lewisian Complex.

TABLE 7. Summary of the post-Lewisian Geological History of central Raasay. The Brecciated Torridonian is omitted because its age is unknown.

emplacement is unknown. It seems likely that this fault is of late Tertiary age although it cannot be proved. The small fault blocks, 250m southeast of Beinn a Chapuill (573 438) and at South Screapadal (582 442), would appear to be directly related to the Holoman-Screapadal Fault.

The Central Raasay Fault trends approximately north-south and throws the middle Great Estuarine Group against the upper Bearreraig Sandstone Formation with a throw in excess of 110m. To the east of the fault the Jurassic dips at about 15 to 20° towards the west. To the west of the fault there is a series of smaller faults trending north-south which are clearly associated with the Central Raasay Fault. This has created a number of fault-bounded blocks that have different dips. All the faults downthrow to the east. These faults cut the Tertiary sills and clearly postdate the igneous activity. This interpretation differs strongly from that of Bradshaw and Fenton, 1982 (p. 142) who relied too strongly on aerial photographs and not on field mapping (they have numerous errors on their map).

TERTIARY TILTING.

Both the Torridonian and the Jurassic dip at about 20° towards the west indicating the whole area has been tilted. Evidence from amygdale strings in the dolerite sills proves that this tilting occurred after the intrusion of the sills. The Central Raasay Fault is probably associated with this tilting.

10. ECONOMIC GEOLOGY

IRONSTONE. The Raasay Ironstone was mined in southern Raasay during the first world war. The ironstone present in central Raasay is similar to that in northern Skye (Anderson and Dunham, 1966 p. 198) and probably not rich enough for extraction.

OIL SHALE. The Cullaidh Shale is a bituminous shale and locally represents a true oil shale in Raasay, but it is doubtful if it could be worked economically.

LEAD. A narrow vein with a high galena content cuts the Lewisian on the foreshore 300m northeast of Brochel Castle (587 463). This suggests that there could be economic deposits of lead on Raasay.

PEAT. There are extensive deposits of peat in central Raasay. Most are small and unmappable but there are larger areas of peat bog and these are the sources of many of the small streams, eg. 1km southwest of South Screapadal. The thickness of the majority of deposits is unknown but at least 2m is visible in a road cutting 1.9km north of Glame (563 446). Peat has long been cut for fuel on Raasay and many small peat cuttings are still in use.

WATER. The small population of southern Raasay derive their water supply from Loch na Mna (579 387). No water from central Raasay is used for public supply.

11. CONCLUSION

The more important conclusions drawn from this survey are presented in list form below.

1. The Lewisian has a geological history similar to that of the southern Scottish Mainland. The main difference is that more phases of Laxfordian folding are present in Raasay.
2. Soft sediment deformation is widespread in the lacustrine siltstone and braided stream sandstones of the Torridonian. This indicates synsedimentary tectonic activity.
3. The Toarcian is developed differently from southern Raasay, with the Portree Shales extending up to the bifrons zone and the Raasay Ironstone having a striatulum subzone fauna.
4. Great Estuarine Group. The Cullaidh Shale-Elgol Sandstone represents a coarsening upwards deltaic sequence. Cylindrobullina is recorded from the Valtos Sandstone of Raasay for the first time. The Duntulm Formation was found in situ.
5. The "vents" recorded by the BGS are reinterpreted as some form of collapse structure.
6. A large number of dolerite sills have been intruded into the Jurassic. The presence of intervening Jurassic sediments and chilled margins indicates they are not plateau basalts.
7. The Torridonian has been folded into a gentle anticline.
8. During the Tertiary the area was tilted towards the west with the formation of a number of faults. This happened after the igneous activity.
9. The area was extensively glaciated.

10. The Jurassic belemnite fauna is of Northern European affinity and has few species in common with Yorkshire (see Appendix 2).

APPENDIX 1. LEWISIAN METAMORPHISM

Two metamorphic events are recognized in the Lewisian, the D3 and D7 events.

THE D3 METAMORPHIC EVENT.

A thin section cut through a Scourie dyke shows a high amphibolite facies assemblage with no retrogressive effects. See figure 20. This sample was obtained 700m north of Brochel Castle (586 471). The following metamorphic assemblage is present,

Hornblende + Andesine + Magnetite + Sphene + Quartz
+ Biotite/Muscovite.

Tarney and Weaver, 1987, found that quartz-dolerite was the most common type of Scourie dyke found in the Assynt Region. These have a mineralogy of: Plagioclase + Pyroxene + Quartz + Biotite + Titaniferous Magnetite. The following reactions are indicated;

Pyroxene ⟶ Hornblende + Quartz

Titaniferous Magnetite ⟶ Magnetite + Sphene

This has produced characteristic reaction coronas of sphene around magnetite cores.

Biotite ⟶ Muscovite

This reaction has produced muscovite fish within biotites due to the formation of small shears in the biotites. This is due to K-metasomatism during the major Laxfordian shearing event.

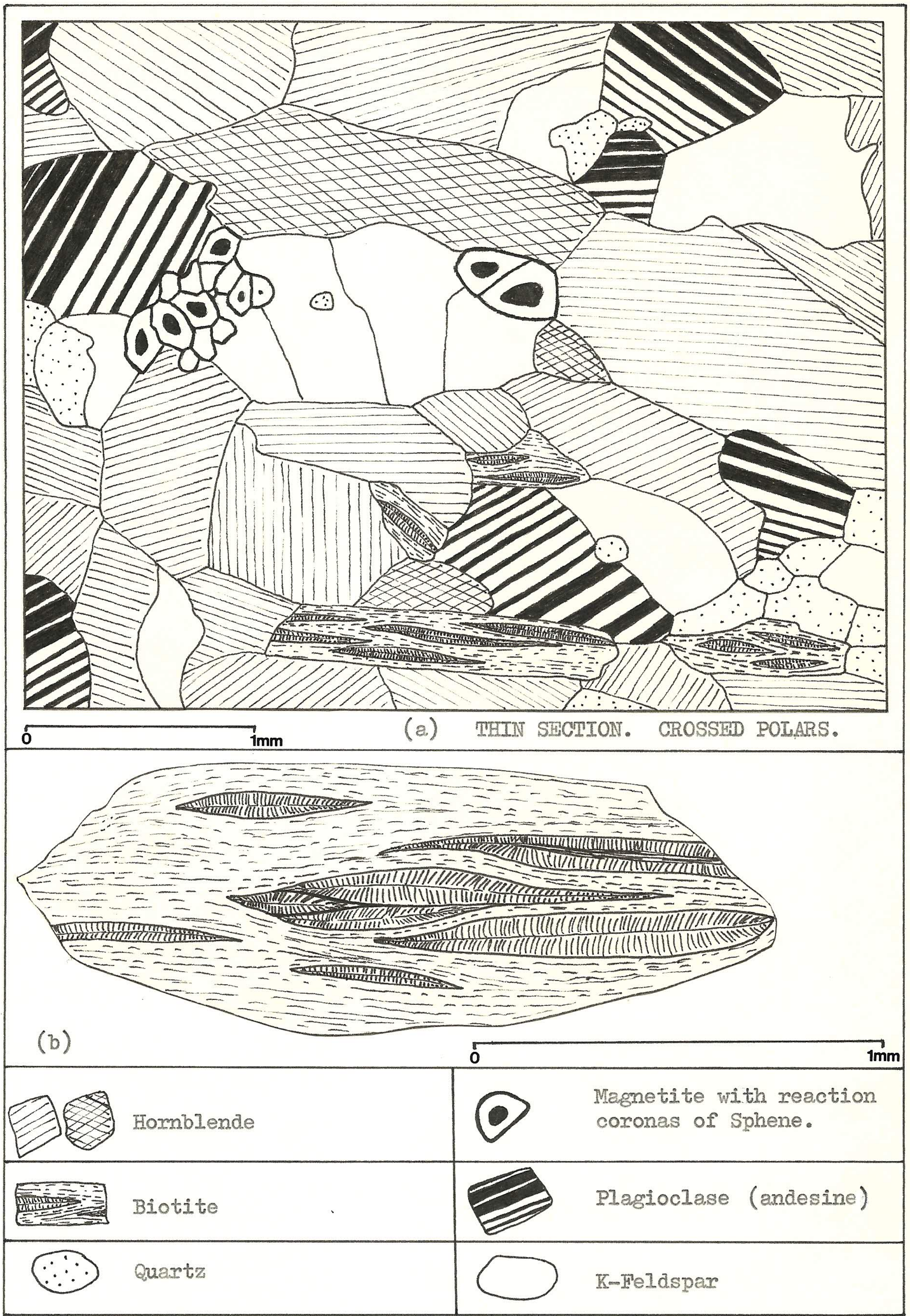


FIGURE 20. D3 Amphibolite Facies Metamorphic Event.

(a) Scourie dyke in amphibolite facies.

(b) Enlargement showing muscovite fish produced in a biotite by shearing.

The radial structure developed in the muscovites is presumably due to subsequent recrystallization (possibly the only indication of retrogressive metamorphism in this section).

THE D7 METAMORPHIC EVENT

A thin section cut in a gneiss shows retrogressive metamorphism to greenschist facies. See figure 21. The sample was collected at a road cutting 800m north-northeast of Brochel Castle (586 471). The following assemblage is present;

Actinolite + Epidote + Oligoclase + Clinozoisite + Quartz + K-Feldspar + Chlorite/Muscovite.

The following retrogressive reactions are indicated;

Hornblende ⟶ Actinolite + Epidote

This reaction is indicated by the presence of numerous small crystals of epidote intergrown with the actinolite (not shown in figure 21).

Andesine ⟶ Oligoclase + Clinozoisite.

Clinozoisite is intergrown with oligoclase (figure 21b).

Biotite ⟶ Chlorite.

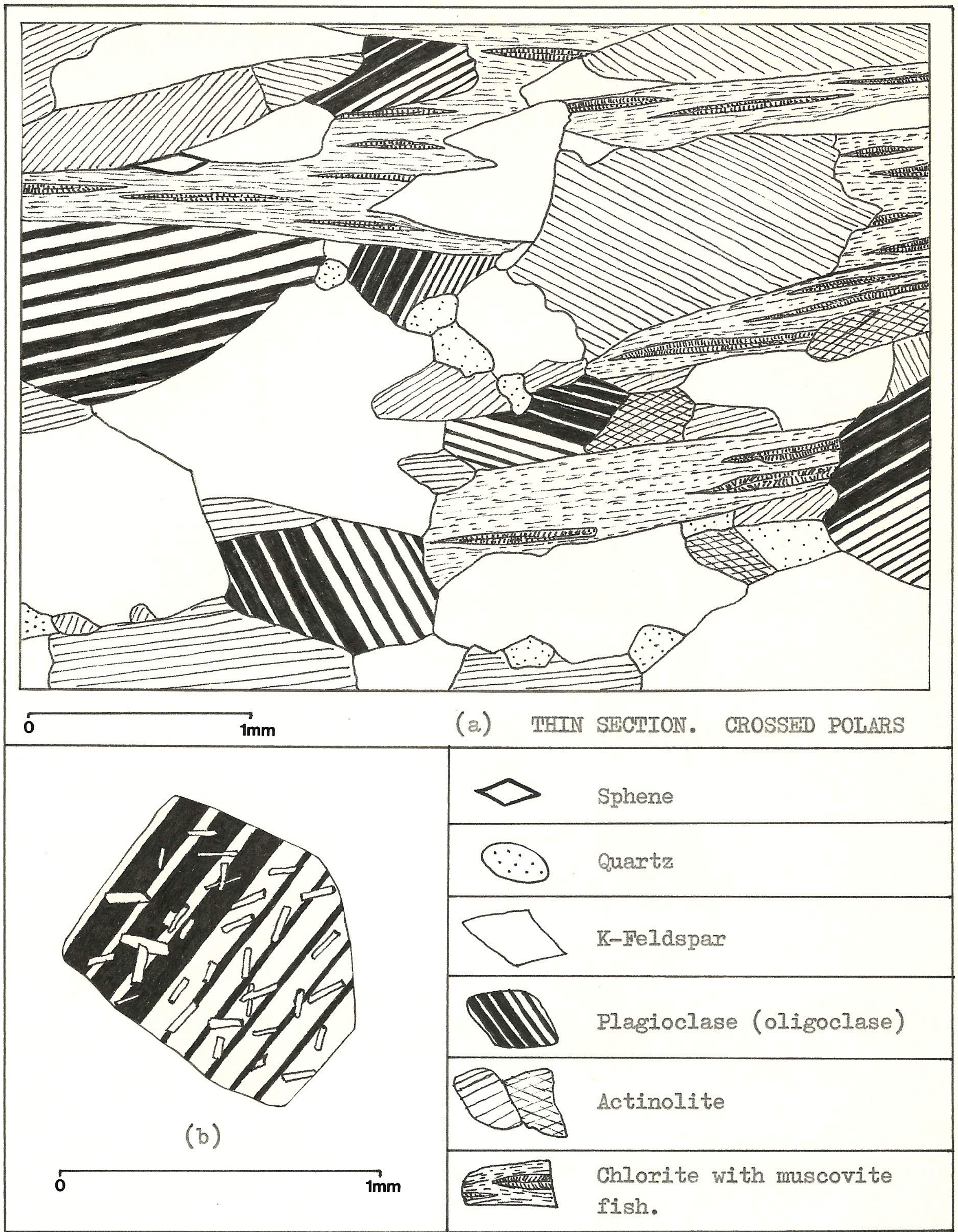


FIGURE 21. D7 Greenschist Facies Metamorphic Event.

(a) Chlorite-actinolite gneiss.

(b) Oligoclase crystal containing small, elongate crystals of clinozoisite.

APPENDIX 2. THE BELEMNITES

The biostratigraphical use of belemnites has necessitated the introduction of new genetic and specific names. These are intended for publication elsewhere but a summary of the most important taxa is given here.

Order BELEMNITIDA

Family PASSALOTEUTHIDIDAE Naef, 1922.

Genus DACTYLOTEUTHIS Bayle, 1878.

Dactyloteuthis curtus, sp. nov. (Figure 9a)

Diagnosis. Very short Dactyloteuthis with a very blunt apex and very weak compression.

Stratum Typicum. Raasay Ironstone, striatulum subzone, central Raasay.

Type. C11332, Mitchell Collection. Striatulum subzone, Raasay.

Distribution. Striatulum subzone; Raasay (abundant) and Cotswolds (rare).

Discussion. Distinguished from D. irregularis by its shorter length, from D. digitalis by its lack of compression and from D. incurvatus by its larger size and blunt apex.

Genus BRACHYBELUS Bayle, 1878.

Brachybelus mucronatus, sp. nov. (Figure 10d and e).

Diagnosis. Short cylindrical Brachybelus with a strongly mucronate apex.

Stratum Typicum. Cephalopod Bed, aalensis subzone, Dursley.

Type. C718, Mitchell Collection; aalensis subzone, Toarcian; Dursley, Gloucestershire.

Distribution. Aalensis and opalinum subzones, Upper Toarcian to Lower Aalenian; Skye and Raasay (uncommon), Cotswolds (common) and Dorset (common).

Discussion. Distinguished from B. cotteswoldia sp. nov. (=Belemnites gingensis Phillips non Oppel) by its shorter length and from Brachybelus insculptus Phillips by its considerably earlier occurrence.

Genus ELLIOTTIBELUS gen. nov.

Diagnosis. Characterized by its great length and by the development of lateral lines of passaloteuthid type and not hastitid type.

Genotype. Hastites junceus (Phillips) emend Lang.

AFFINITIES OF THE BELEMNITE FAUNA.

During the Lower Jurassic two distinct belemnite faunas occur in Europe, the Yorkshire fauna restricted to the Yorkshire basin and the Northern European fauna that ranges from Bavaria to the Cotswolds. Table 8 shows the distribution of the Hebridean belemnites and it is clear that these have close affinity with the Northern European fauna.

During the Middle Jurassic these faunal distinctions disappeared and more uniform faunas appeared.

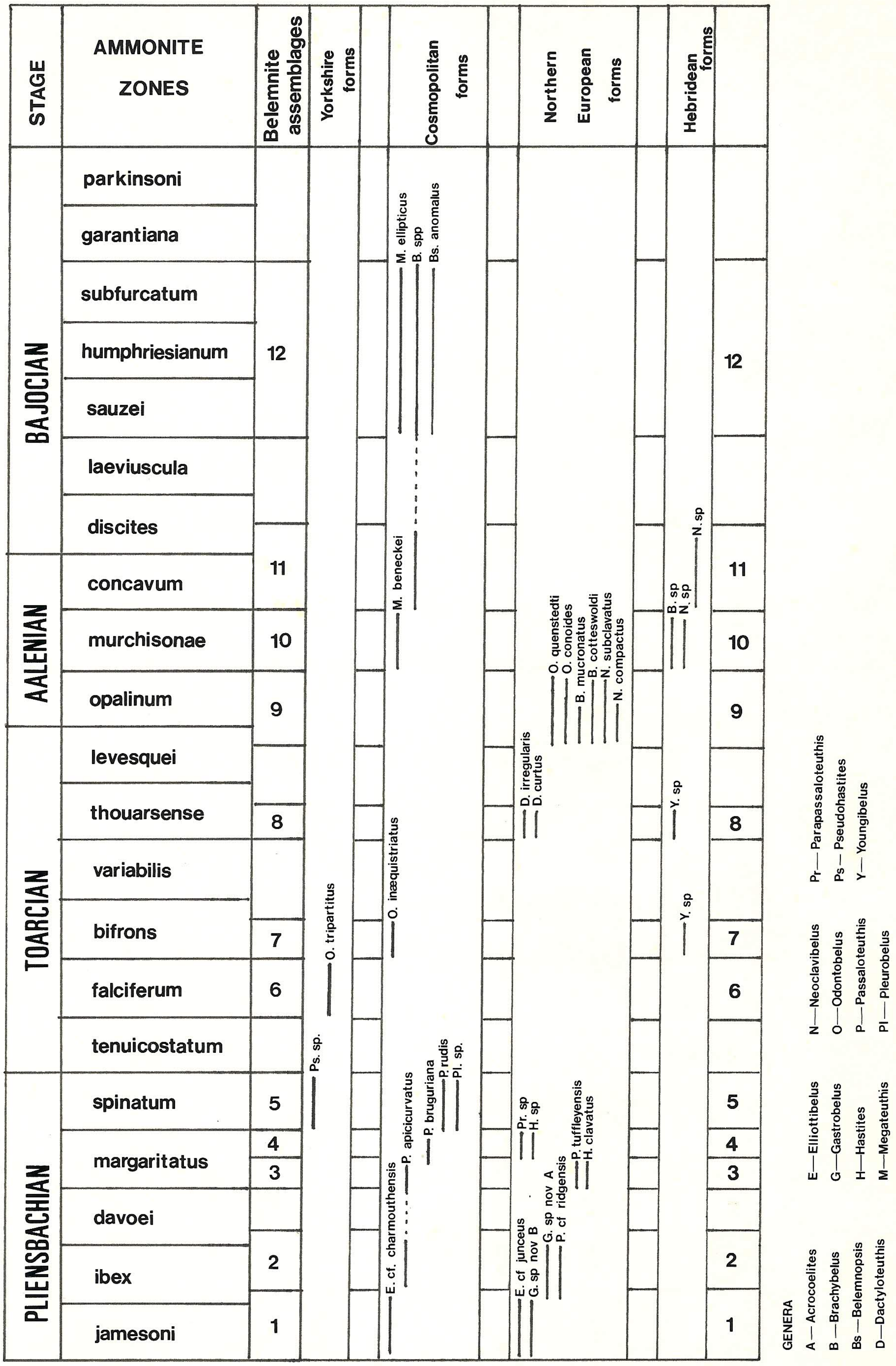


TABLE 8. The Belemnite Fauna of the Inner Hebrides (Skye and Raasay). Note predominance of Northern European Forms.

APPENDIX 3. PETROLOGY OF THE TERTIARY DOLERITE

Thin sections of one dyke and two sills were cut. One of the sills had an intergranular texture while the other sill and the dyke had ophitic textures. No significant differences were observed between the dyke and the sills, therefore only the two different textures are described here.

INTERGRANULAR TEXTURE. Figure 22.

Sample taken from a small sill 1.7km ENE of Brae (577 423).

MINERALOGY

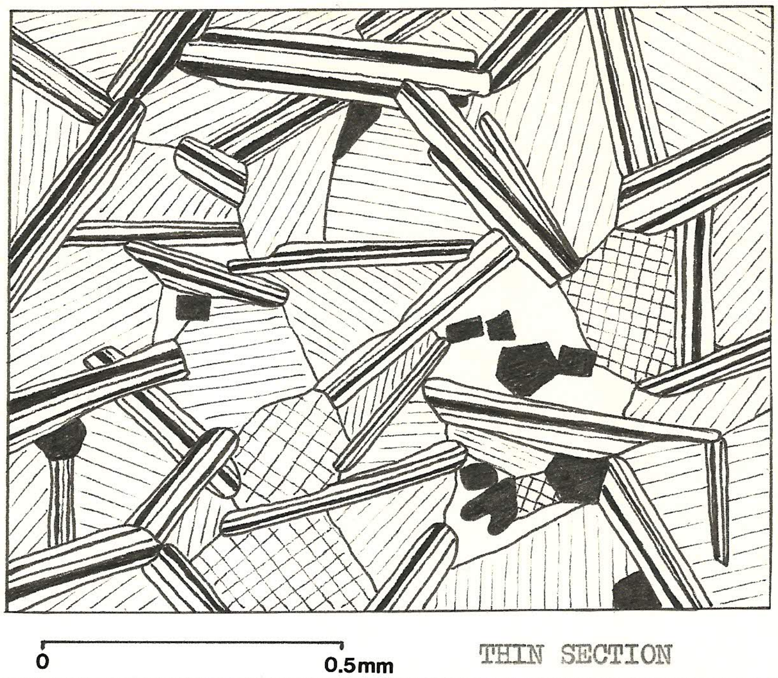
Plagioclase. Euhedral crystals up to 0.6mm long. Occasional phenocrysts up to 5mm in size occur but none are shown in figure 22.

Clinopyroxene. Anhedral crystals up to 0.5mm in size.

Magnetite. Euhedral crystals up to 0.1mm in size. Sometimes occur in small clusters.

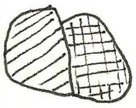
Biotite. Occurs mainly around clusters of small magnetites.

CRYSTALLIZATION. The magnetites and the plagioclases crystallized first (there were two phases of plagioclases, the phenocrysts and the small euhedral crystals). The biotite then crystallized around the magnetites before the clinopyroxene completed the crystallization process.



THIN SECTION

Plagioclase



Clinopyroxene.

Serpentinized olivine

Magnetite

Biotite

KEY FOR FIGURES 22 AND 23.

FIGURE 22. Dolerite sill with intergranular texture. Crossed polars.

OPHITIC TEXTURE, Figure 23.

Olivine-dolerite sill with well developed ophitic texture, 2km ESE of Brae (580 411).

MINERALOGY.

Plagioclase. Euhedral laths up to 0.5mm long.

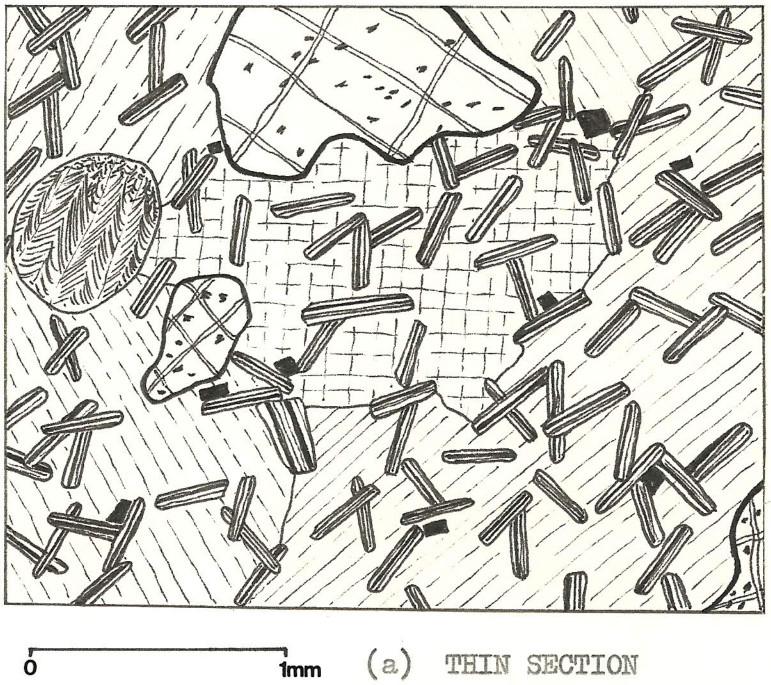
Olivine. Rounded crystals up to 2mm in size and partially altered to serpentine.

Clinopyroxene. Large anhedral crystals up to 4mm in size ophitically enclosing the plagioclase laths

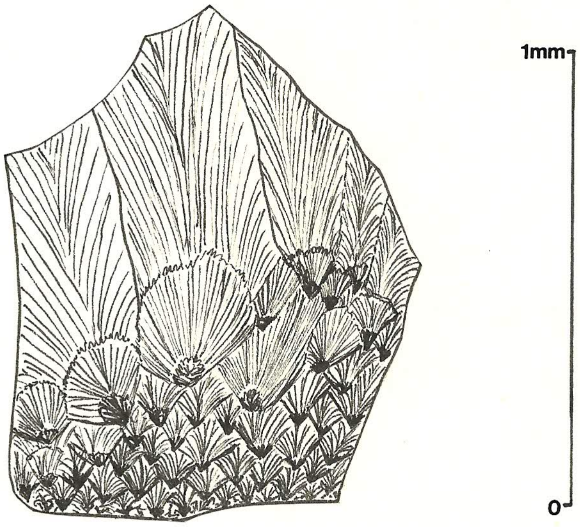
Magnetite. Euhedral crystals up to 0.1mm in size

Amygdales. Up to 4mm in size and composed of fibrous zeolites.

CRYSTALLIZATION. The olivine crystallized before the feldspars since the olivine does not contain feldspars. The magnetites and plagioclases were next to crystallize before everything was enclosed in pyroxene plates. The zeolites were encased in the pyroxene still as liquids, hence their shape, and were the last phase to crystallize.



(a) THIN SECTION



(b)

FIGURE 23. Amygdaloidal olivine-dolerite sill.
(a) Diagram showing ophitic texture in crossed polars.
(b) Detail showing internal structure within an amygdale containing fibrous zeolite.

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