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Basement weathering at the Lower Palaeozoic unconformity in the Channel Islands and northern Brittany

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Deep weathered profiles are developed in igneous basement rocks immediately beneath the Lower Palaeozoic elastic sequences of Alderney, Jersey and northern Brittany. The weathering features are interpreted to have developed during the early Palaeozoic. In western Alderney, homogeneous quartz diorite host rocks are relatively uniformly decomposed whereas jointed porphyry dykes preserve spectacular corestone weathering morphologies. In central southern Alderney the diorite basement exhibits only a thin weathered skin but is mantled in a degraded sequence of rotten corestone boulders, interpreted to represent fossil colluvium. At an inland locality in northern Alderney, degraded diorite profiles feature *in-situ* corestones. Rotten corestones are also present at the unconformity surface and are included in the overlying fluvial sediments. Basement weathering at the unconformity surface in Jersey can only be positively identified at one locality. Here angular fragments of rhyolitic breccia are preserved spalled from weathered rhyolite profiles and are interbedded with alluvial fan sediments. On the Côtes du Nord, northern Brittany, a 7m thick sequence of homogeneously degraded granodiorite occurs beneath alluvial fan deposits. Although the evidence is not fully conclusive, this weathering profile might also have developed in the early Palaeozoic.

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Introduction

Palaeosols have most commonly been described from alluvial sequences (e.g. Allen 1974, 1986). However, in another guise, they may also be preserved at unconformities in situations where subaerial exposure and weathering of basement rocks has preceded subsequent deposition (e.g. Wahlstrom 1948; Williams 1968). This paper describes weathering phenomena from the Lower Palaeozoic unconformity in the Channel Islands and northern France. These weathering features are interpreted to be of early Palaeozoic, possibly Cambrian age.

The studied sequences are developed in igneous basement rocks unconformably overlain by Lower Palaeozoic strata on the Channel Islands of Alderney (Alderney Sandstone Formation), and Jersey (Rozel Conglomerate Formation) and on the Côtes du Nord, northern Brittany (Fréhel Formation) (Figs 1 and 2).

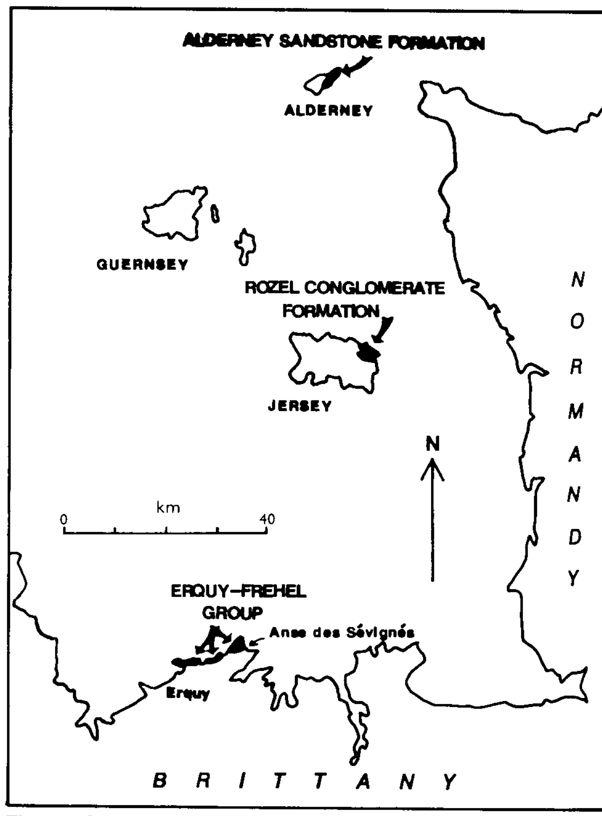

Figure 1. Location of study area sequences and other places mentioned in text.

Alderney

Evidence of deep weathering of the late Precambrian basement is preserved at the unconformity with the Alderney Sandstone Formation in three places on Alderney: at the western outlier, at Bluestone Bay, and at a railway cutting in NE Alderney (Fig. 3).

Western Outlier

A map delimiting the extent of the Alderney Sandstone Formation and the varied basement lithologies present at the western outlier is shown in Fig. 3b. The Cotil Breccia member (Went 1989) of the Alderney Sandstone Formation is in contact with granitic basement at this locality. This member is c.12m thick and consists of locally derived, poorly sorted breccio-conglomerates grading up into bedded and locally cross-stratified, granular sandstones. These lithologies wedge out against the basement to the NW (within c. 100m), suggesting that they may have been restricted to a small palaeovalley. The presence of desiccation cracks in the finer lithologies of this member confirms that deposition took place in a subaerial environment. Deposition probably occurred by a combination of colluvial and stream processes (Went 1989). On the coast two principal basement lithologies are present; an early Cadomian quartz diorite and later porphyry dykes.

The quartz diorite is coarse-grained, exhibits pencil quartz and localised gneissose fabrics, and contains strained mafic dykes, mafic xenoliths and thin acid dykes. For 6m or more beneath the unconformity this rock shows a degraded, pitted texture due to differential weathering of the constituent minerals. In addition, mafic dykes and xenoliths are recessed whilst thin acid veins and dykes stand out as resistant `walls' (Fig. 4a). It would appear that the host rock disaggregated on weathering to form a coarse granitic sand. Away from the unconformity this lithology exhibits a more robust appearance and is relatively smooth due to marine erosion,

Porphyry dykes intrude the quartz diorite. The dykes are systematically jointed, with one prominent set of joints running parallel with the margins of the intrusions. Where present within a few metres of the unconformity, intense weathering has occurred along

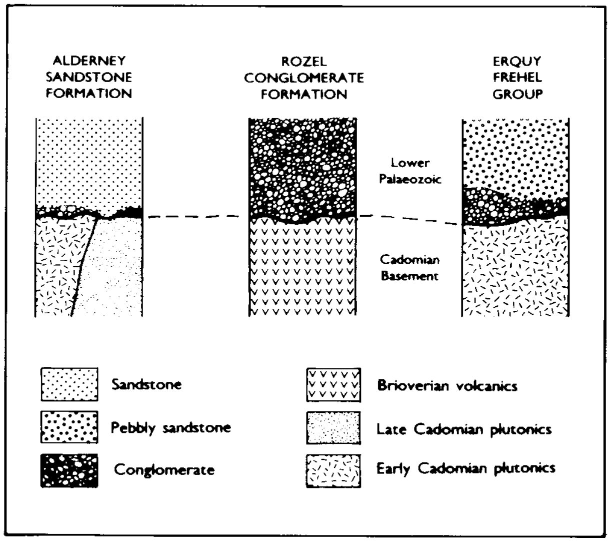

Figure 2. Summary of the basement-cover relationships at the Lower Palaeozoic unconformity in the Channel Islands and northern Brittany.

the joint sets and as a result the dykes display spectacular corestone weathering morphologies (Fig. 5a). Porphyry cobbles and boulders are common in the overlying sediments. Moreover, they are the predominant constituent of the gravel size fraction. Cobbles of quartz diorite are extremely rare (Figs. 4a, 5b). This is recognised as resulting from the contrasting weathering styles of the foliated quartz diorites and the jointed porphyry dykes at the time of deposition.

The restriction of the decomposed lithologies to positions close to the unconformity and the occurrence of fragments of weathered basement (in the form of porphyry corestones and rare weathered quartz diorite clasts) in the overlying sediments (cf. Retallack 1986) strongly suggests that the weathering occurred immediately prior to deposition. The two contrasting morphologies exhibited by the deep weathered residua are recognised as resulting from differences in the composition, texture and structure of the host lithologies. The saprolite preserved at this locality may constitute the lower part of what was a more extensive weathering profile, the upper, less resistant layers having possibly been removed by erosion immediately prior to deposition.

Bluestone Bay

At the west end of Bluestone Bay, the Alderney Sandstone rests unconformably on diorites of the late Cadomian Central Diorite (Figs 3a, 5c). The contact, shown in more detail in Fig. 6, has previously been described as faulted (Mourant 1933; Sutton and Watson 1970; Pudsey 1977). However, during the course of this study no evidence has been found to substantiate such a conclusion, a view shared by Laffoley (1986). The Bluestone Bay Sandstone member of the Alderney Sandstone Formation overlies the basement at this locality. This member, which occurs interbedded with fluvial sandstones of the Becquets Sandstone at the east end of Bluestone Bay, consists predominantly of submature, parallel laminated sandstone of possible beach and nearshore origin (Went 1989). Three main lithological components may be recognised at the unconformity at this locality: the basement diorites, a heavily decomposed red conglomerate, and a sequence of pale coloured, laminated sandstones.

The diorite beneath the unconformity is blue-grey in colour, relatively fine-grained, reasonably fresh and contains localised xenoliths, patches of appinite, and poorly developed orbicular structures (cf. Nockolds 1931). For a metre or so beneath the conglomerate, it also exhibits a sheeted fracture system which is associated with minor corestone development (Fig. 6). As is clear in Fig. 5c, there are several metres of relief on the unconformity surface, the overlying conglomerate resting in a palaeotopographic low and wedging out northwards up the cliff. The laminated sandstones which in turn overlie the conglomerate onlap, and in part drape, the basement relief (Fig. 5c).

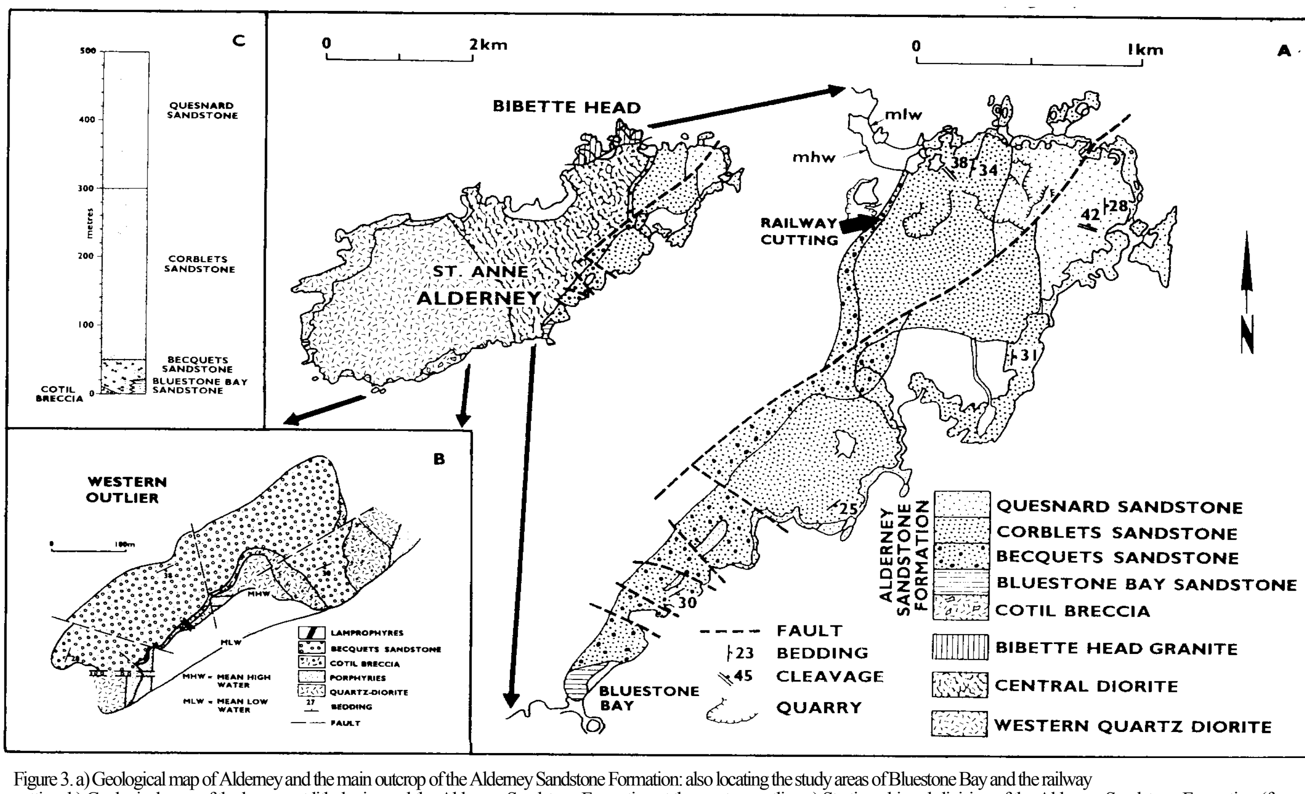

Figure 3. a) Geological map of Alderney and the main outcrop of the Alderney Sandstone Formation: also locating the study areas of Bluestone Bay and the railway cutting. b) Geological map of the basement lithologies and the Alderney Sandstone Formation at the western outlier. c) Stratigraphic subdivision of the Alderney Sandstone Formation (from Went 1989).

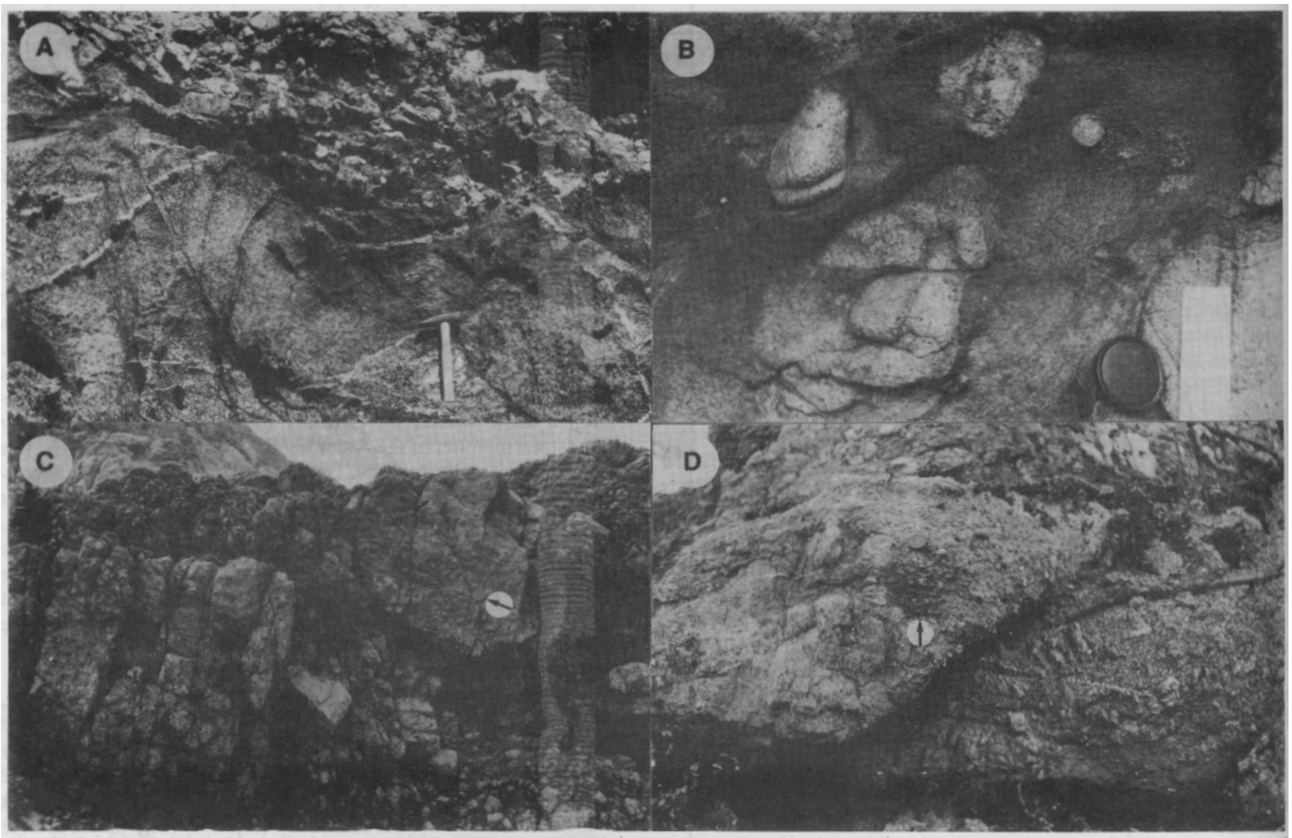

Figure 4. a) Pitted texture exhibited by degraded quartz diorite basement immediately beneath the unconformity with the Cotil Breccia (Alderney). Note that thin acid veins stand proud from the host rock. Hammer gives scale. b) Detailed view of the red conglomerate immediately above the unconformity at Bluestone *Bay* (Alderney) consisting of well rounded cobbles and boulders of diorite set in a matrix of granular mud. Note that some thoroughly decomposed clasts (faintly defined) are virtually indistinguishable from the matrix. Lens cap gives scale. c) Weathered rhyolite from beneath La Trête des Hougues (Jersey). Note the highly brecciated appearance of the rhyolite (bottom right). Lens cap (arrowed) gives scale. d) Unconformity (arrowed) between weathered rhyolite and unbedded rhyolitic talus breccia, La Tête des Hougues, (Jersey). Lens cap directly above arrow gives scale.

The conglomerate is of slightly variable thickness (averaging 600-800mm) and is in sharp contact with the diorite. It is composed mainly of rounded diorite cobbles and boulders, set in a degraded, muddy, but granular textured matrix. One exceptionally large diorite boulder at beach level measures approximately 3m x 1.5m in size. Rare clasts of vein quartz and appinite are also locally present but exotic clasts and sandstone boulders are absent. The diorite clasts exhibit varying degrees of degradation. Some are relatively indurated, whilst others are thoroughly decomposed and virtually indistinguishable from the matrix (Fig. 4b). The contact between the conglomerate and the overlying sandstone is irregular in form. Several of the rounded diorite clasts protrude through the top of the conglomerate bed. A few are completely incorporated into the sandstone. The laminations in the earliest deposited sandstones are contiguous with the form of the protruding clasts and indicate the draping of an irregular surface.

The sedimentary nature of the contact between the sandstone and the conglomerate indicates that this part of the sequence is *in-situ* and not faulted. The clasts in the conglomerate must clearly have been derived from nearby exposures in the diorite. The highly rounded and decomposed nature of the diorite clasts suggests their origin as corestones from a weathered regolith (cf. Williams *et al.* 1987; Williams 1968). The matrix of the conglomerate is recognised as thoroughly decomposed diorite. The fracturing in the diorites immediately beneath the unconformity recalls the sheeting commonly present in igneous rocks exposed to the processes of unroofing and exfoliation. Such fractures typically run subparallel with the ground surface (Bowen *et al.* 1972). That the fracture system might record a period of fossil weathering is further supported by its association with corestones. The sharp contact between the diorite and the conglomerate, however, suggests that the weathering phenomena present at this locality do not form part of a profile developed *in situ.* The cobbles, boulders and matrix that make up the conglomerate, however, are clearly local in origin and are interpreted to have accumulated as colluvium at the foot of a slope (cf. Bowen *et al.* 1972, text plate 6.2). This was perhaps, the local palaeoslope visible in Fig. 5c.

Railway Cutting

The main features of the exposure of the unconformity and the basal parts of the Alderney Sandstone Formation at the railway cutting are shown in Fig. 7. At the time of the field study the unconformity was very poorly exposed and had to be excavated. This contact has previously been described by Pudsey (1977) as faulted and by Laffoley (1986) as an *in-situ* sequence. During the course of this study no evidence has been found which would suggest any significant fault movement. The basement at this locality is of diorite similar to that at Bluestone Bay, belonging to the late Cadomian Central Diorite. The overlying sandstones belong to the Becquets Sandstone member of the Alderney Sandstone Formation. These are granular, locally pebbly and most commonly trough cross-stratified preserving unidirectional palaeocurrents. The member has been interpreted to be of braided fluvial origin (Went 1989). It forms the basal part of a 500m thick evolving fluvial sequence (Went and Andrews 1990).

The unconformity at this locality exhibits a small amount of relief even over the short section studied. The diorite closest to the unconformity in the two shortest excavations is a soft, red, granular textured material, barely recognisable as diorite. In the middle trench several intensely weathered, rounded diorite boulders occur embedded in this material. This soft, red rock gives way downwards into decomposed but indurated and more clearly recognisable, jointed diorite. The transition is a rapid one. In the deeper parts of the longest trench, spherical masses of relatively indurated

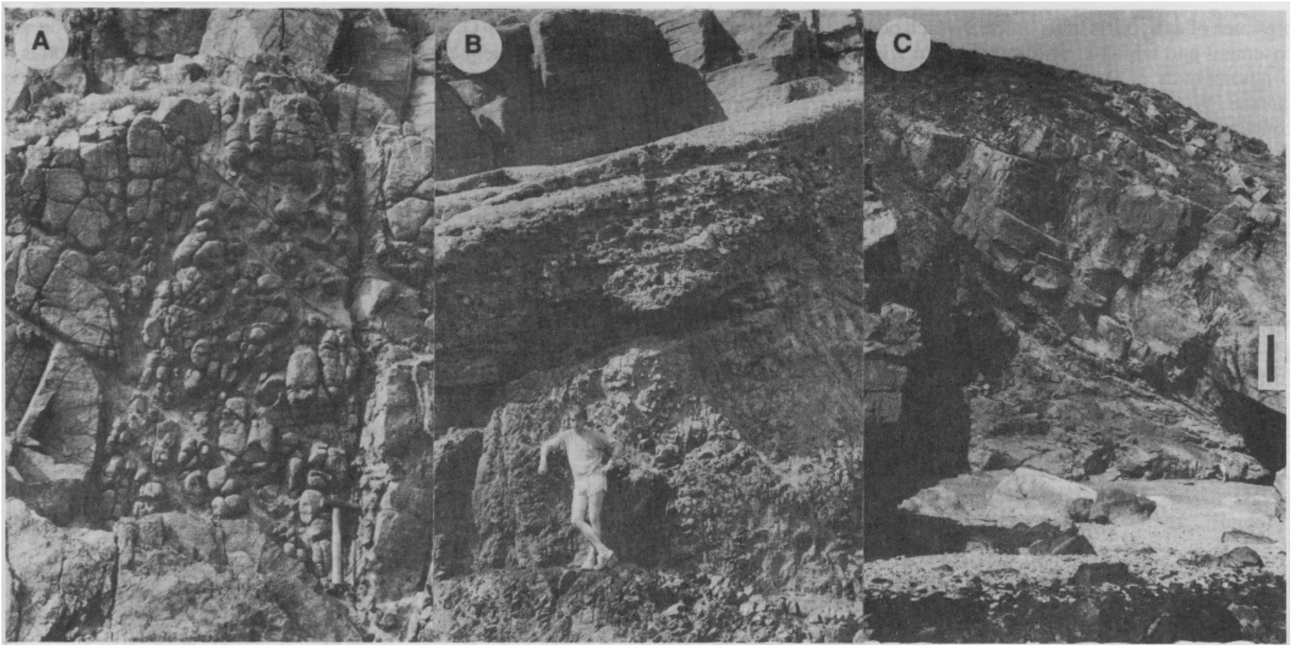

Figure 5. a) Corestone weathering morphology exhibited by the jointed porphyry dyke in the centre of the bay at the western outlier (Alderney). Hammer gives scale. b) Unconformity between jointed porphyry dyke and the Cotil Breccia at the eastern margin of the western outlier (Alderney). Note the typical corestone weathering style of the porphyry basement and the presence of common rounded porphyry cobbles in the overlying conglomerate. c) Unconformity between basement diorites and the Bluestone Bay Sandstone at the western end of Bluestone Bay (Alderney). Note the relief on the unconformity surface. Scale bar = 3m.

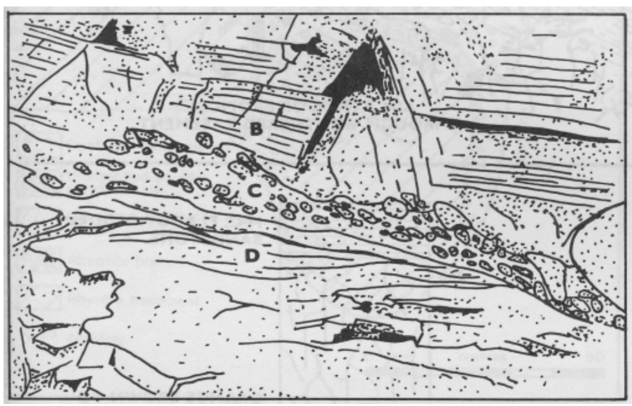

Figure 6. Line drawing (from photograph) of the unconformity at Bluestone Bay illustrating the sheeted fracture system present in the basement diorites, the red conglomerate of rounded decomposed diorite boulders, and the overlying laminated sandstones. The boulder conglomerate is around 600-800mm thick.

diorite occur in otherwise decomposed basement. These are recognised as corestones similar to those present in the jointed porphyry dykes at the western outlier. The details of the relationships between the different types of weathered diorite are shown fully in Fig. 7b, c. The contact with the overlying sandstone is quite sharp. The lowermost sandstone beds are coarse-grained, flaggy bedded and locally contain decomposed, rounded cobbles of diorite. Succeeding sandstones are coarser grained, granular and trough cross-stratified (Fig. 7a).

The flaggy bedded character of the initial sandstones is suggestive of deposition by shallow flows (Harms *et a1.* 1975), such as is likely with the deposition of the earliest sediments onto a slight topographic high. The degraded, rounded diorite clasts included in these sandstones are interpreted as corestones that may have suffered continued weathering on the palaeolandsurface before becoming incorporated into the earliest sediments (cf. Bowen *et al.* 1972, text plate 6.5). Their presence gives strong support to the suggestion that the basement weathering occurred immediately prior to the deposition of the sandstones. It is also clear evidence for an *in-situ* sequence at this unconformity.

The soft red, thoroughly decomposed `muddy' diorite present in the two shortest trenches directly beneath the unconformity rests on more indurated (but still weathered) diorite. It is apparently restricted to a slight palaeotopographic low and locally contains corestones (Fig. 7c). In this respect it is similar to the basal conglomerate at Bluestone Bay. These features suggest that some downslope movement of corestone cobbles and thoroughly decomposed diorite in the form of a colluvium, may have occurred at this locality also.

Jersey

The unconformity in Jersey between the Rozel Conglomerate Formation and the late Precambrian (Brioverian) volcanic basement is exposed at only two localities, La Tête des Hougues and Vicard Point (Fig. 8a). At Vicard Point, conglomerate is in sharp contact with a rhyolite basement which shows no evidence of *in situ* weathering. The following section concentrates on the exposed unconformity at La Tête des Hougues.

La Tête des Hougues

A map delimiting the extent of the four main lithological units present at La Tête des Hougues is shown in Fig. 8b. These are (i) basement rhyolites, (ii) a locally derived rhyolitic breccia, (iii) silty sandstones and small pebble conglomerates, and (iv) chaotic-textured and stratified coarse-grained conglomerates. The latter two units are of alluvial fan origin (Went *et al.* 1988).

The unconformity at this locality is well exposed over an area of roughly 50m^2 and is clearly seen to exhibit several metres of relief. In some places stratified exotic conglomerate rests directly on smoothly eroded rhyolite whilst in others basement weathering is preserved (Fig. 4c). The rhyolites exhibit a variety of original depositional features, including localised flow banding and more commonly chaotic textures resulting from autoclastic disruption and brecciation. Superimposed on the depositional disruption are the effects of early Palaeozoic weathering. These two contrasting effects were not clearly separated by Went *et al.* (1988) in their brief description of this weathered basement. It is now recognised that the primary control on the morphology of the weathered profile at this locality is probably retained by the original autobreccia. Weathering processes, however, clearly did operate on the basement in early Palaeozoic times. This is evidenced by the presence of a rhyolitic talus breccia which occurs spalled from the basement and which is also interbedded with exotic alluvial fan conglomerates of the main Rozel Conglomerate Formation sequence (Went et al. 1988, figure 4). Weathering was apparently concentrated along joints and between autobreccia blocks. These lines of weakness are stained a deep red-purple colour and are weathered back. Local weathering was clearly productive in yielding abundant, but typically small (a few centimetres to tens of centimetres diameter) angular fragments of rhyolite, as these form a distinctive breccia bed up to lm thick in the centre of the cove (Fig. 4d, 8b).

Northern Brittany

The Erquy-Fréhel Group crops out on the Côtes du Nord, northern Brittany and comprises the Erquy and Fréhel Formations. The Fréhel Formation overlaps the Erquy Formation eastwards onto Cadomian basement of the Fort de la Latte complex (Went and Andrews 1991). The contact between the Erquy Formation and underlying sequences is not exposed. The Fréhel Formation is in contact with basement granodiorites on the coast in the Anse des Sévignés (Fig. 1). Here red-stained decomposed granodiorite, exhibiting weathering styles similar to that of the degraded quartz diorite at the outlier in Alderney, occurs beneath a lenticular body of coarse chaotic-textured boulder conglomerate and a succeeding sequence of pebble conglomerates. These two lithofacies sequences have been interpreted as canyon-fill and alluvial fan deposits respectively (Went and Andrews 1991). Unlike in Alderney and Jersey, there is no positive way of determining whether the basement weathering at this locality developed as an early Palaeozoic phenomenon or at a later date. It is recognised that Tertiary weathering affects the rocks of the area (Esteoule-Choux 1983) and that it might be the case that the weathering of the granodiorite in the Anse des Sévignés occurred during this period. However, an early Palaeozoic age for the weathering is considered

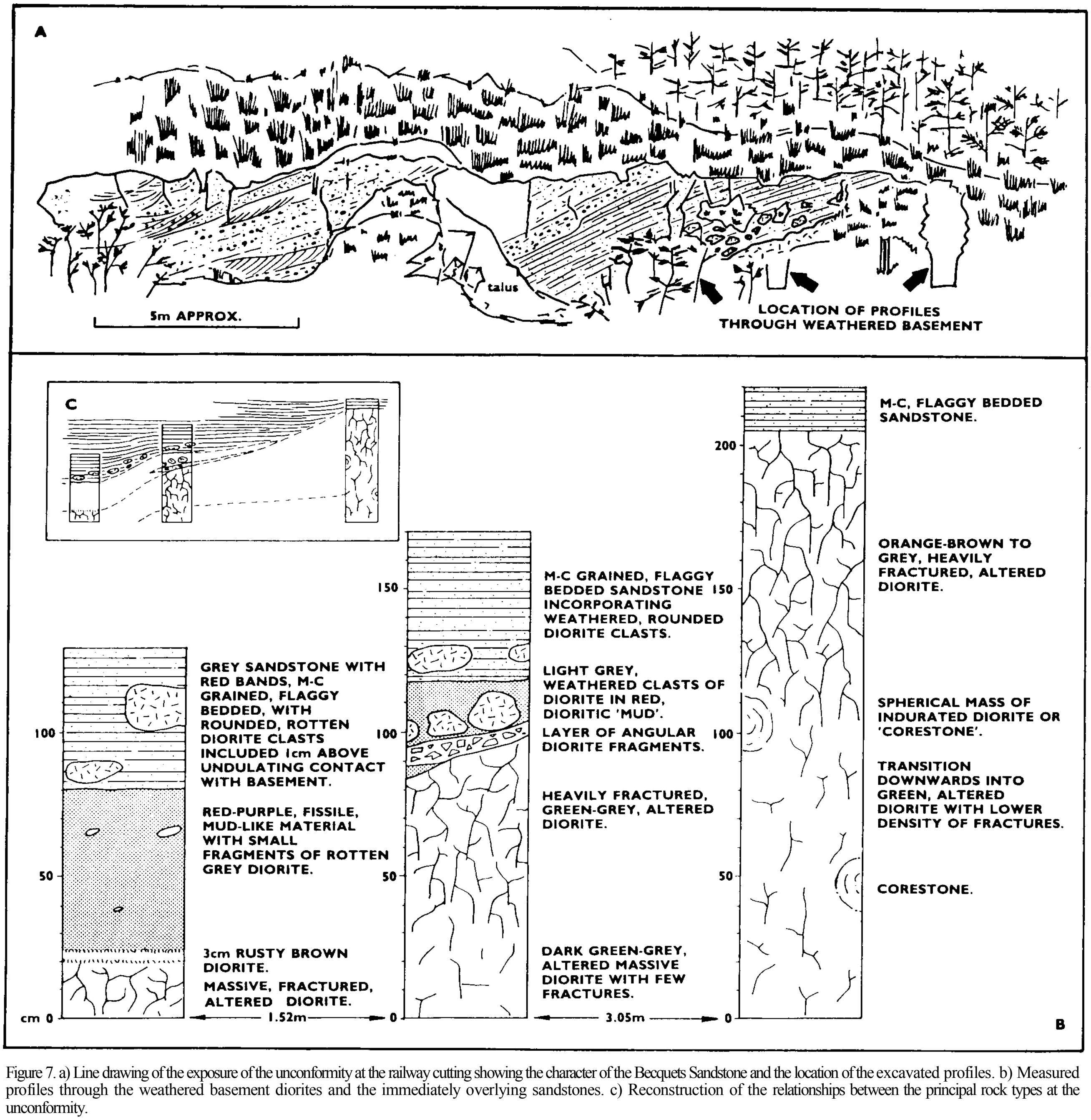

Figure 7. a) Line drawing of the exposure of the unconformity at the railway cutting showing the character of the Becquets Sandstone and the location of the excavated profiles. b) Measured profiles through the weathered basement diorites and the immediately overlying sandstones. c) Reconstruction of the relationships between the principal rock types at the unconformity.

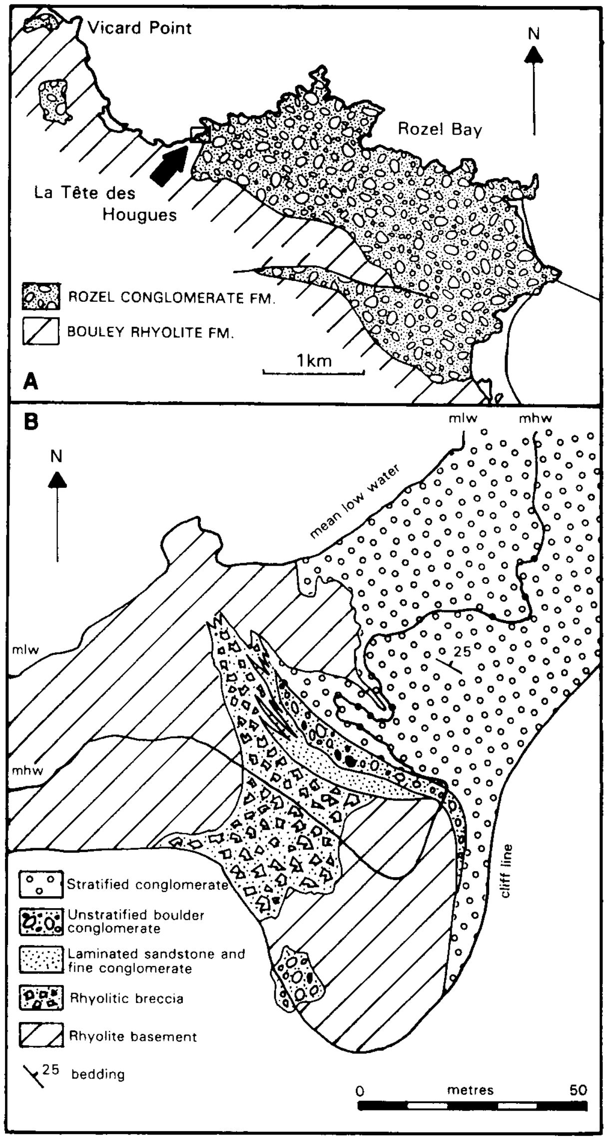

Figure 8. Location (a) and geological map (b) of the cove beneath La Tête des Hougues, Jersey, C.I.

a strong possibility in view of the fact that the zone of weathering appears to be confined to an area near to the unconformity. Where examined elsewhere along the coast, the granitic basement appears unweathered.

Conclusions

1. Weathered profiles through igneous basement rocks occur beneath the Lower Palaeozoic red-bed sequences of the Channel Islands and northern Brittany.

2. The morphology of the weathered profiles is controlled primarily by the texture, composition and structure of the host lithologies. Coarse-grained quartz diorites on Alderney and granodiorites in northern Brittany exhibit a relatively homogeneous rotting due to differential weathering of the constituent minerals. In contrast, fine-grained diorites and porphyry dykes on Alderney have weathered along joints to yield corestone residuals. The autobrecciated rhyolites of Jersey show weathering concentrated along the natural discontinuities to liberate angular blocks and fragments.

3. The incorporation of fragments of the weathered mantle into the overlying sediments (in the form of talus wedges and corestones) suggests that the weathered profiles developed in the early Palaeozoic at the time of deposition.

Deposition of the Alderney Sandstone Formation, Rozel Conglomerate Formation and Erquy-Fréhel Group has been related to a phase of post-Cadomian rifting and 'molasse' sedimentation (Went and Andrews 1990). If this scenario is a realistic one then the weathering may have been initiated in response to the uplift and subaerial exposure of the Cadomian belt during the Cambrian. This would make these weathering profiles (to the best of the authors knowledge) the second oldest recorded from the UK. Only the weathering profiles described form the Lewisian-Torridonian unconformity, in NW Scotland (Williams 1968) are older.

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References

Allen, J.R.L. 1974. Studies in fluviatile sedimentation: implications of pedogenic carbonate units in the Lower Old Red Sandstone, Anglo Welsh outcrop. *Geological Journal, 9,* 181-208.

Allen, J.R.L. 1986. Pedogenic calcretes in the Old Red Sandstone facies, (late Silurian - early Carboniferous) of the Anglo-Welsh area, southern Britain. *In:* Wright, V.P. (ed.) *Paleosols,* Blackwell Scientific, Oxford, 58-86.

Bowen, D.Q., Atkinson, B.W., Davies, B.E. and Simmons, I.G. 1972. A *Concise Physical Geography.* Hulton Educational Publications Limited, 338p.

Esteoule-Choux, J. 1983. Kaolinitic weathering profiles in Brittany: genesis and economic importance. *In:* Wilson, R.C.L. (ed.) Residual deposits: surface related weathering processes and materials. *Geological Society Special Publication, 11,* 33-38.

Harms, J.D., Southard, J.B., Spearing D.R. and Walker, R.G. 1975. Depositional environments as interpreted from primary sedimentary structures and stratification sequences. *Society of Economic Palaeontologists and Mineralogists, Short course 2, Dallas.*

Laffoley, N. d'A. 1986. The Alderney Sandstone. *Transactions of the Société Guernesiase, 22,* 97-109.

Mourant, A.E. 1933. The geology of the Channel Islands. *Unpublished PhD thesis, Oxford,* 195p.

Nockolds, S.R. 1931. Orbicular diorite from the Island of Alderney. *Geological Magazine, 68,* 499-506.

Pudsey, C.J. 1977. Geologica Ridunae. *Transactions of the Société Guernesiase, 20,* 259-282.

Retallack, G. 1986. Re-appraisal of a 2200Ma palaeosol near Waterval, Onder, South Africa. *Precambrian Research, 32,* 195-232.

Sutton, J. and Watson, J. 1970. The Alderney Sandstone in relation to the ending of plutonism in the Channel Islands. *Proceedings of the Geologists' Association, London, 18,* 577-584.

Wahlstrom, E.E. 1948. Pre-Fountain and recent weathering on Flagstaff Mountain near Boulder, Colorado. *Geological Society of America Bulletin,* 59, 1173-1190.

Went, D.J., Andrews, M.J., and Williams, B.P.J. 1988. Processes of alluvial fan sedimentation, basal Rozel Conglomerate Formation, La Tête des Hougues, Jersey, Channel Islands. *Geological Journal, 23,* 75-84.

Went, D.J. 1989. Sedimentology of the Lower Palaeozoic Rozel Conglomerate Formation (Jersey), Alderney Sandstone Formation and Erquy-Frêhel Group (northern Brittany). *Unpublished PhD thesis, University of Bristol.*

Went, D.J. and Andrews, M.J. 1990. Post-Cadomian erosion, deposition and basin development in the Channel Islands and northern Brittany. In: D'Lemos, R.S., Strachan, R.A. and Topley, C.G. (eds) The Cadomian Orogeny, *Geological Society Special Publication, 51,* 293-304.

Went, D.J. and Andrews, M.J. 1991. Alluvial fan, braided stream and possible marine shoreface depositional sequences of the Lower Palaeozoic Erquy-Frêhel Group, northern Brittany. *Proceedings of the Ussher Society,* 7, 385-391.

Williams, G.E. 1968. Torridonian weathering and its bearing on Torridonian palaeoclimate and source. *Scottish Journal of Geology, 4,* 164-184.

Williams, M.A.J., Abell, P.I. and Sparks, B.W. 1987. Quaternary landforms, sediments, depositional environments, and gastropod isotope ratios of Adrar Bous, Tenere Desert, Niger, south central Sahara. *In:* Frostick, L.E. and Reid, I. (eds), Desert Sediments Ancient and Modern. *Geological Society, Special Publication, 35,* 105-125.