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Report of a walkover survey and desk study of rock exposures within southwest England.

Marine, Coastal and Hydrocarbons Programme

Open Report OR/07/018

BRITISH GEOLOGICAL SURVEY

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H M Evans.

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1 Introduction

Within the EU Habitats Directive a scientific reserve exists for Special Areas of Conservation (SACs) in four marine habitats, detailed in Table 1. In order to designate SACs, a significant knowledge of the nature of the sea bed and its character is required. Offshore geophysical surveys involving singlebeam echo sounders, multibeam echo sounders, sidescan sonars and sub-bottom profilers help to provide such information. However, the interpretation of this data may be increased through investigation of terrestrial analogues for the offshore geology and structure. Indeed, such investigation prior to marine survey may

- highlight potential difficulties in marine data analysis,
- influence offshore survey location and coverage and
- aid analysis of marine survey data outputs.

EU Code	Habitat Name
1110	Sandbanks which are slightly covered by sea water all the time
1170	Reefs
1180	Submarine structures made by leaking gases
8330	Submerged or partially submerged sea caves

Table 1. Habitats considered for SAC selection in UK waters, adapted from Aish et al (2007).

This project, funded by Natural England, aims to provide detailed information on the location and character of Habitats Directive Annex 1 reef features within two areas lying offshore of Cornwall, around the Lizard and west of Land's End (hereafter called Cape Bank). In order to achieve this, the British Geological Survey (BGS), in partnership with the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) and the United Kingdom Hydrographic Office (UKHO), is gathering and interpreting data on the sea bed conditions in both of these areas. Terrestrial analogues for the likely offshore geology and structure were also sought with the aim of improving the value of the initial data and easing the identification of reef features.

2 Methodology

This report describes examples of terrestrial rock exposures, primarily at the coast, as analogues for rock and sediment at the sea bed within the two offshore study areas.

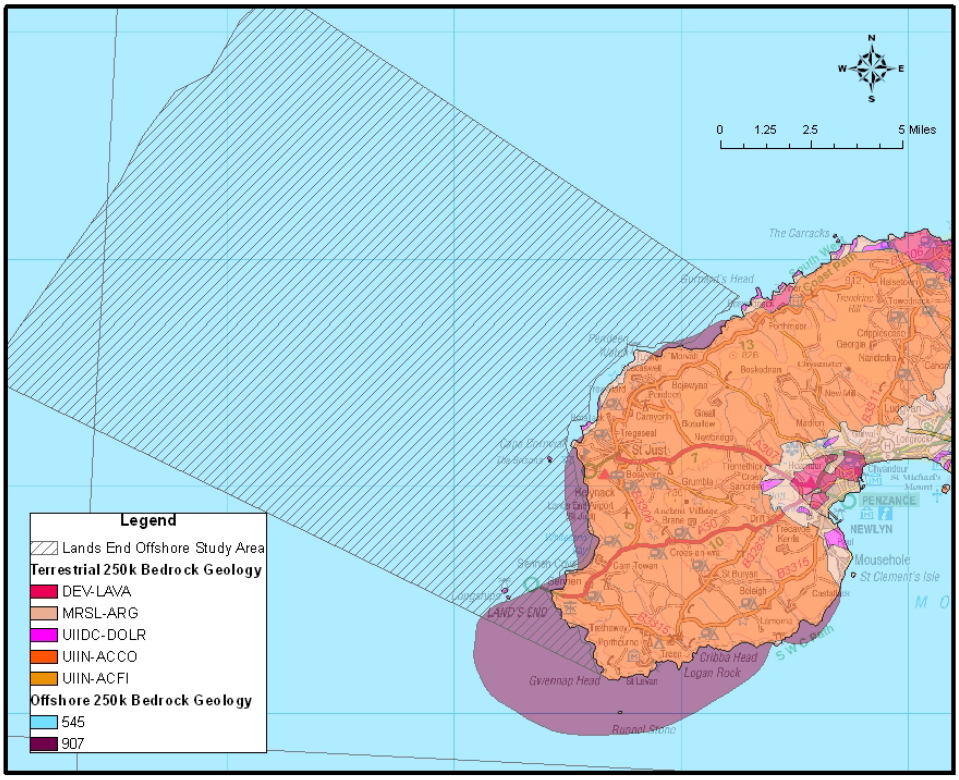

Figure 1a. Cape Bank offshore study area. See Table 2 for explanation of figure legend.

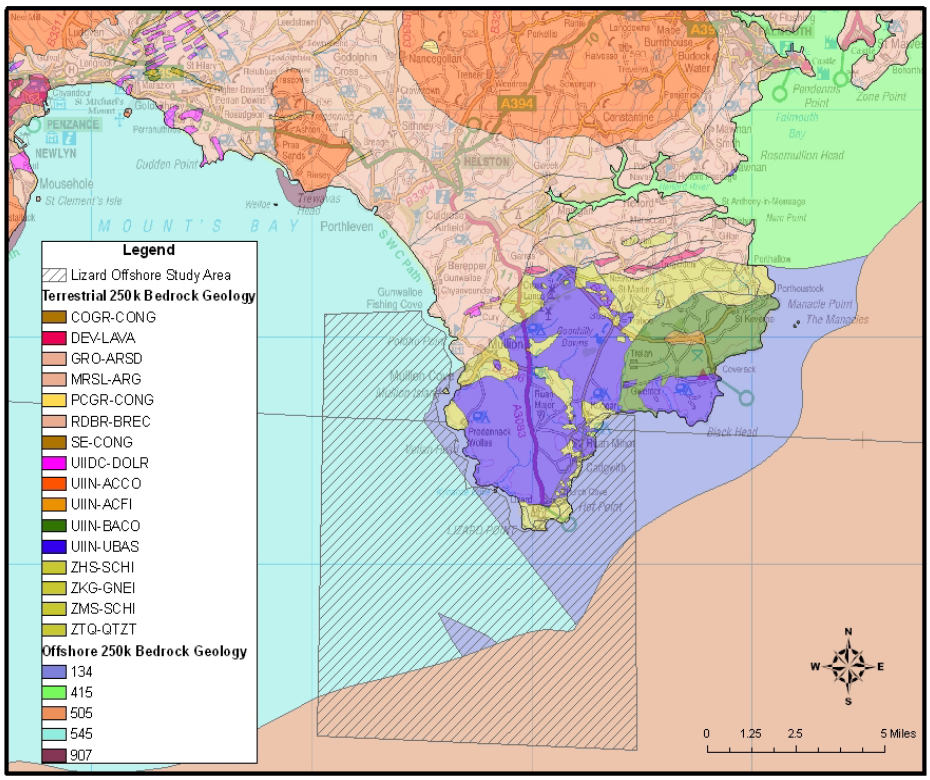

Figure 1b. Lizard offshore study area. See Table 2 for explanation of figure legend.

The solid (bedrock) geology within the two offshore study areas is published in BGS 1:250 000 Geological Map Sheet 49N 06W (Lizard) Solid (BGS, 1983) and BGS 1:250 000 Geological Map Sheet 50N 06W (Land's End) Solid (BGS, 1985). Figure 1 is based on these maps and allows the identification of potential offshore geology when used in conjunction with the legend key in Table 2. Existing literature including BGS memoirs, geological maps and published texts were examined to find terrestrial sites within south west England exhibiting geology analogous to that of the offshore study areas.

Offshore 250k Bedrock Geology	
Figure 1 Legend Code	**Geology**
134	Lizard Complex Peridotite & Serpentinite
415	Devonian (undifferentiated) Slate & Sandstone
505	Permian and Triassic Mudstone, Siltstone & Sandstone
545 (North)	Devonian and Carboniferous (undifferentiated) Slate
545 (South)	Devonian and Carboniferous (undifferentiated) Mudstone, Sandstone & Limestone
907	Land's End Granite
Terrestrial 250k Bedrock Geology	
Figure 1 Legend Code	**Geology**
COGR-CONG	Crousa Gravels-Conglomerate
DEV-LAVA	Devonian Rocks-Lava or Extrusive Igneous Rock
GRO-ARSD	Gramscatho Group-Argillaceous Rocks and Sandstone
MRSL-ARG	Mylor Slate Formation-Argillaceous
PCGR-CONG	Polcrebo Gravels-Conglomerate
RDBR-BREC	Roseland Breccia Formation-Breccia
SE-CONG	St Erth Formation-Conglomerate
UIIDC-DOLR	Unnamed Igneous Intrusion Devonian to Carboniferous-Dolerite
UIIN-ACCO	Unnamed Igneous Intrusion- Acid and Coarse-grained
UIIN-ACFI	Unnamed Igneous Intrusion- Acid and Fine-grained
UIIN-BACO	Unnamed Igneous Intrusion-Basic and Coarse-grained
UIIN-UBAS	Unnamed Igneous Intrusion-Ultrabasic
ZHS-SCHI	Lizard Hornblende Schists-Schist
ZKG-GNEI	Kennack Granite and Gneiss-Gneiss
ZMS-SCHI	Lizard Mica Schists-Schist
ZTQ-QTZT	Treleague Metaquartzite-Quartzite

Table 2. Key to geology displayed in Figure 1. The offshore geology colours identified here are continued in Table 3 and section 3 for ease of comparison. Rocks bearing legend Code 415 lie outside of the offshore study area and are not considered further.

Examination of terrestrial exposures of similar rock types will ease interpretation of offshore survey data, so aiding identification of reefs suitable for SAC designation. In places the classification of offshore geology from the existing geological maps proves especially simple; for example large proportions of the Cape Bank and Lizard study areas are interpreted as 'Devonian and Carboniferous (undifferentiated) mudstone, sandstone and limestone'. Where this occurs terrestrial analogues for all potential marine rock types were studied so improving understanding of sea bed nature and character. Following this desk study the field sites detailed in Table 3 and Figure 2 were identified as suitable.

Geology	Location	Grid Reference
Lizard Complex Peridotite & Serpentinite		
Serpentinite & Gabbro (Early-mid Devonian)	1 Coverack	SW783185
Peridotite & Serpentinite (Early-mid Devonian)	2 Kynance	SW685133
Additional Igneous		
Dolerite & Gabbro (Devonian/ Carboniferous)	3 Perranuthnoe	SW539292
Devonian Mudstone, Sandstone and Limestone		
Pendower Formation (Mid Devonian)	4 Pendower	SW905383
Portscatho Beds (Mid Devonian)	5 Portscatho	SW879352
Devonian Slate		
Mylor Slate & Gramscatho Beds (Devonian)	6 Porthleven	SW644241
Mylor Slate (Late Devonian)	7 Godrevy Point	SW580433
Carboniferous Mudstone, Sandstone and Limestone		
Boscastle Formation (Late Devonian/Early Carboniferous)	8 Boscastle	SX097916
Crackington Formation (Late Carboniferous)	9 Crackington Haven	SX142969
Bude Formation (Late Carboniferous)	10 Widemouth Bay	SS197024
Land's End Intrusion		
Biotite Granite (Late Carboniferous)	11 Porthcurno	SW388222
Biotite Granite (Late Carboniferous)	12 Porth Nanven	SW355309
Permian and Triassic Mudstone, Siltstone and Sandstone		
Bow Breccia (Early Permian)	13 West Sandford	SS811028
Newton St Cyres Breccia (Late Permian)	14 Cromwell's cutting	SS817003
Creedy Park Sandstone (Mid Permian)	15 Building site	SS817003
Exeter Basalt (Early Permian)	16 Posbury Quarry	SX815977

Table 3. Terrestrial field sites. Note colours correspond to the offshore geology identified in Table 2 and Figure 1.

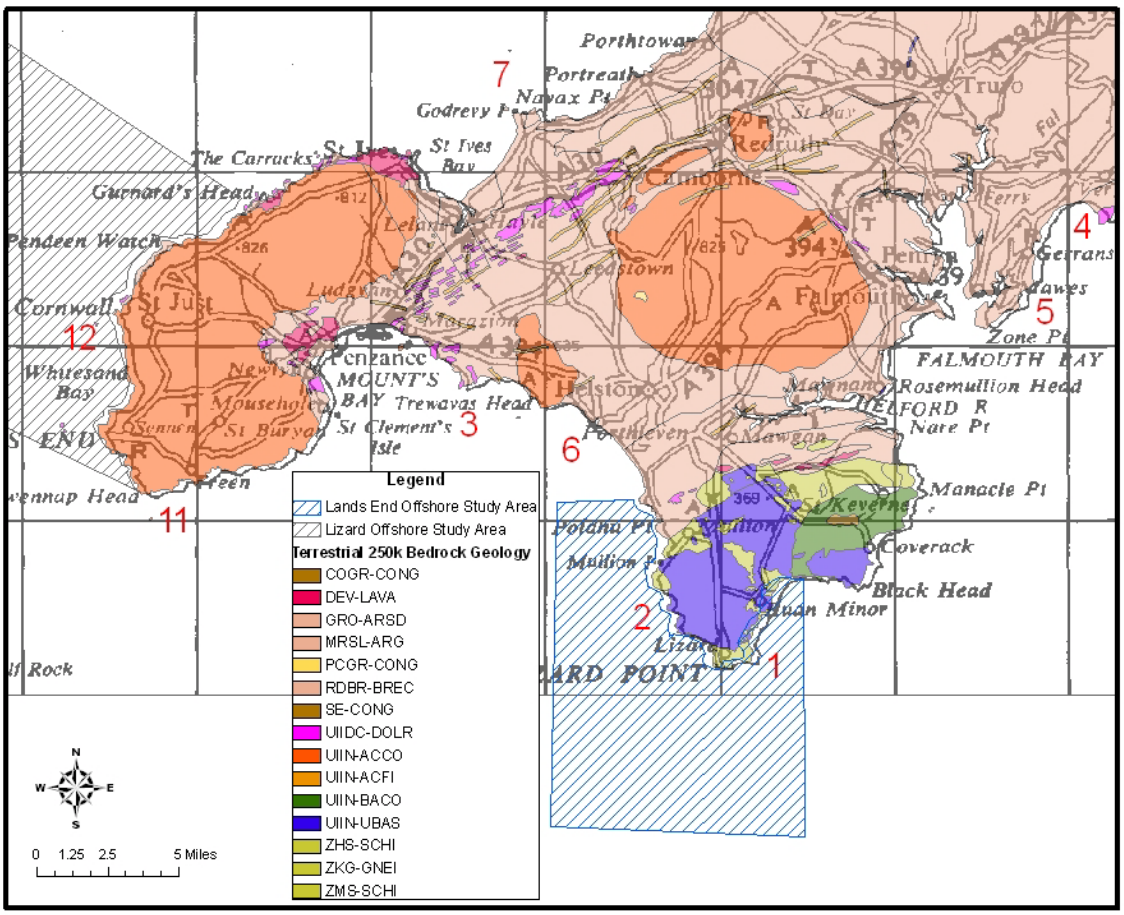

Figure 2a.

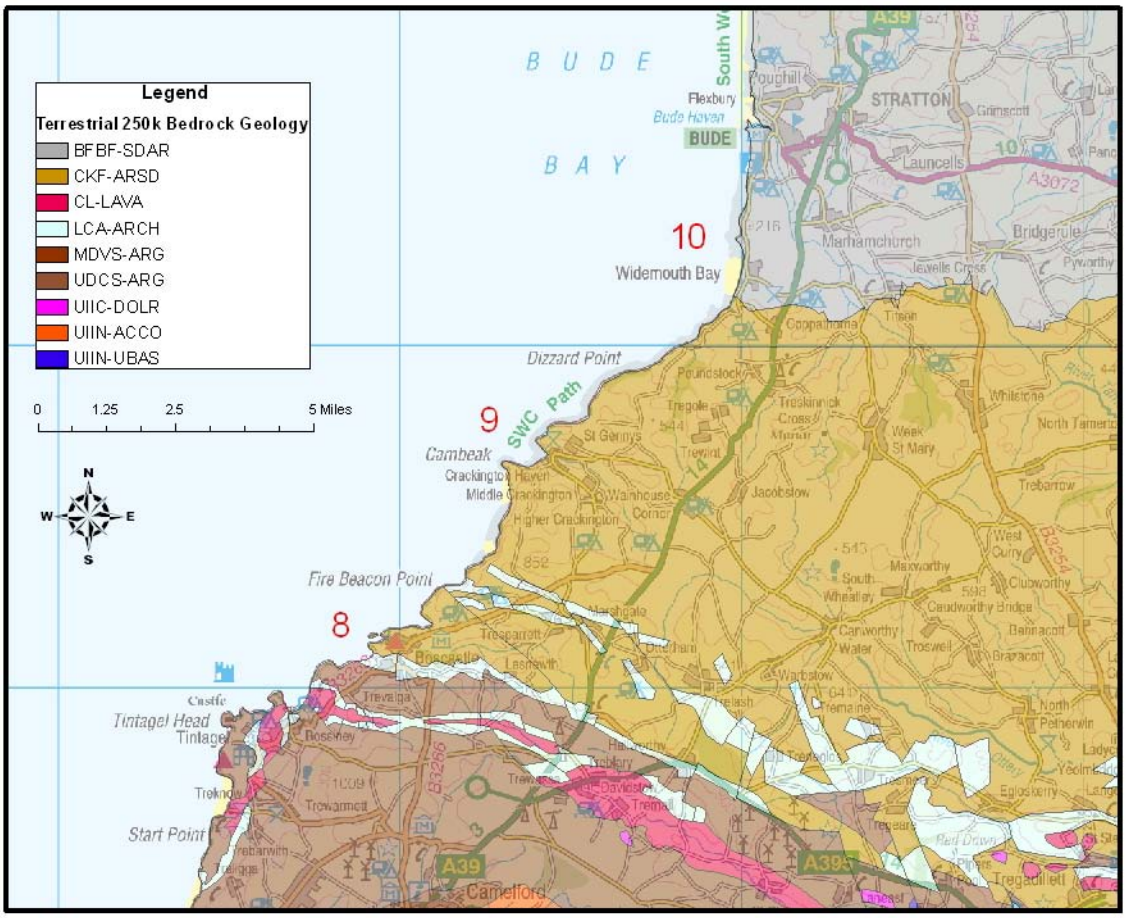

Figure 2b.

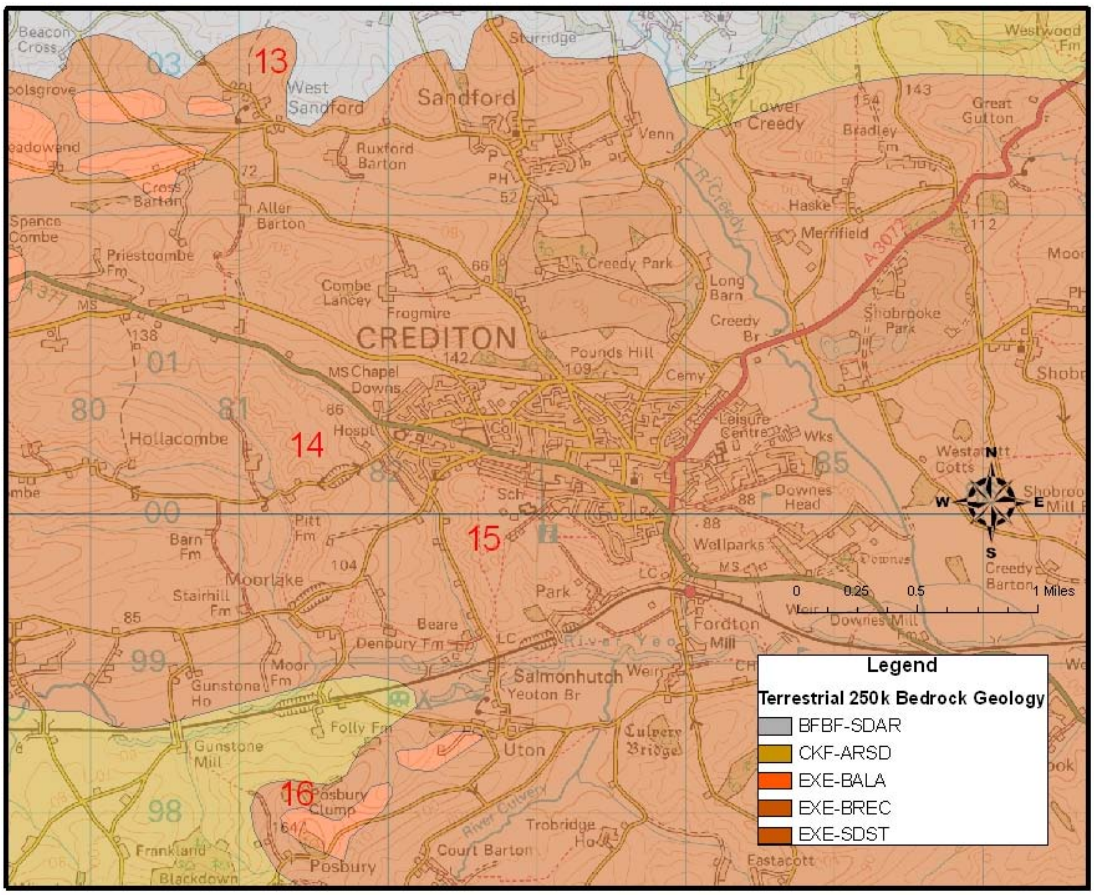

Figure 2c.

Figure 2a, b and c. Terrestrial field sites (site numbers correspond to locations in Table 2). See Table 4 for key to legend.

Terrestrial 250k Bedrock Geology	
Figure 2 Legend Code	**Geology**
COGR-CONG	Crousa Gravels-Conglomerate
DEV-LAVA	Devonian Rocks-Lava or Extrusive Igneous Rock
GRO-ARSD	Gramscatho Group-Argillaceous Rocks and Sandstone
MRSL-ARG	Mylor Slate Formation-Argillaceous
PCGR-CONG	Polcrebo Gravels-Conglomerate
RDBR-BREC	Roseland Breccia Formation-Breccia
SE-CONG	St Erth Formation-Conglomerate
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UIIN-UBAS	Unnamed Igneous Intrusion-Ultrabasic
ZHS-SCHI	Lizard Hornblende Schists-Schist
ZKG-GNEI	Kennack Granite and Gneiss-Gneiss
ZMS-SCHI	Lizard Mica Schists-Schist
BFBF-SDAR	Bude and Bideford Formations-Sandstone and Argillaceous Rocks
CKF-ARSD	Crackington Formation-Argillaceous and Sandstone
CL-LAVA	Carboniferous Limestone Supergroup-Lava or Extrusive Igneous Rock
LCA-ARCH	Lower Carboniferous Rocks-Argillaceous Rocks and Chert
MDVS-ARG	Middle Devonian Slates-Argillaceous
UDCS-ARG	Upper Devonian and Lower Carboniferous Rocks-Argillaceous
EXE-BALA	Exeter Group-Basaltic Lava
EXE-BREC	Exeter Group-Breccia
EXE-SDST	Exeter Group-Sandstone

Table 4. Key to geology displayed in Figure 2.

Examination of the field sites took place from the 16th- 20th July 2007. In total 16 terrestrial locations were visited (an average of 3 per day) and the geology at each site analysed visually, with specific regard to structure and geomorphology. In order to increase the validity of the information gathered at least two different exposures were examined for each potential offshore rock type. The photographic and written evidence collected is presented in section 3 and is divided into summaries organised by rock type and field site. The selected photographs provide representative coverage of the range of geology and structures present at each site.

3 Analysis and Interpretation

3.1 LIZARD COMPLEX PERIDOTITE AND SERPENTINITE

Location	**1 Coverack (SW783185)**
Geology	Peridotite
Age	Early-mid Devonian
Lithological Characteristics	Coverack Cove lies upon a peridotite-gabbro contact with peridotite exposed to the south and gabbro to the north. The peridotite is recognisable as a dark, greenish rock pierced by many troctolite, olivine grabbo and olivine dolerite dykes. The peridotite is reddened where particularly weathered.
Structural Characteristics	The peridotite rocks display a blocky form pierced by dykes.

Approximate width at base of image (clockwise from top left) 0.6m; 3m; 1m and 1.5m.

Location	**2 Kynance (SW685133)**
Geology	Peridotite and Serpentinite
Age	Early-mid Devonian
Lithological Characteristics	Two forms of peridotite are present at Kynance Cove. The primary type is a coarse-grained bastite serpentinite with large enstatite crystals, whilst the secondary is a fine-grained and banded tremolite serpentinite. Talc rich zones exist.
Structural Characteristics	The secondary, recrystallised peridotite displays a higher relief than the primary peridotite. Both forms are highly polished by the tides.

Approximate width at base of image (clockwise from top left) 0.3m; 4m; 1m and 2m.

3.2 ADDITIONAL IGNEOUS

Location	**3 Perranuthnoe (SW539292)**
Geology	Dolerite and Gabbro
Age	Devonian and Carboniferous
Lithological Characteristics	Both the Metabasic rocks (dolerite and gabbro) exhibit a slight green colouring.
Structural Characteristics	A massive structure is present and large boulders have formed in intertidal areas.

Approximate width at base of image (clockwise from top left) 0.5m; 4m; 1m and 3m.

3.3 DEVONIAN MUDSTONE, SANDSTONE AND LIMESTONE

Location	**4 Pendower (SW905383)**
Geology	Pendower Formation
Age	Mid Devonian
Lithological Characteristics	Dark grey cherts, coarse sandstone (beds and lenses), limestone and limestone turbidites are present within the Pendower Formation. All of the above are encased in variously coloured metalliferous mudstones.
Structural Characteristics	Crenulations and interlaminations are present. The bedding dips at approximately 25^{o} East-South-East.

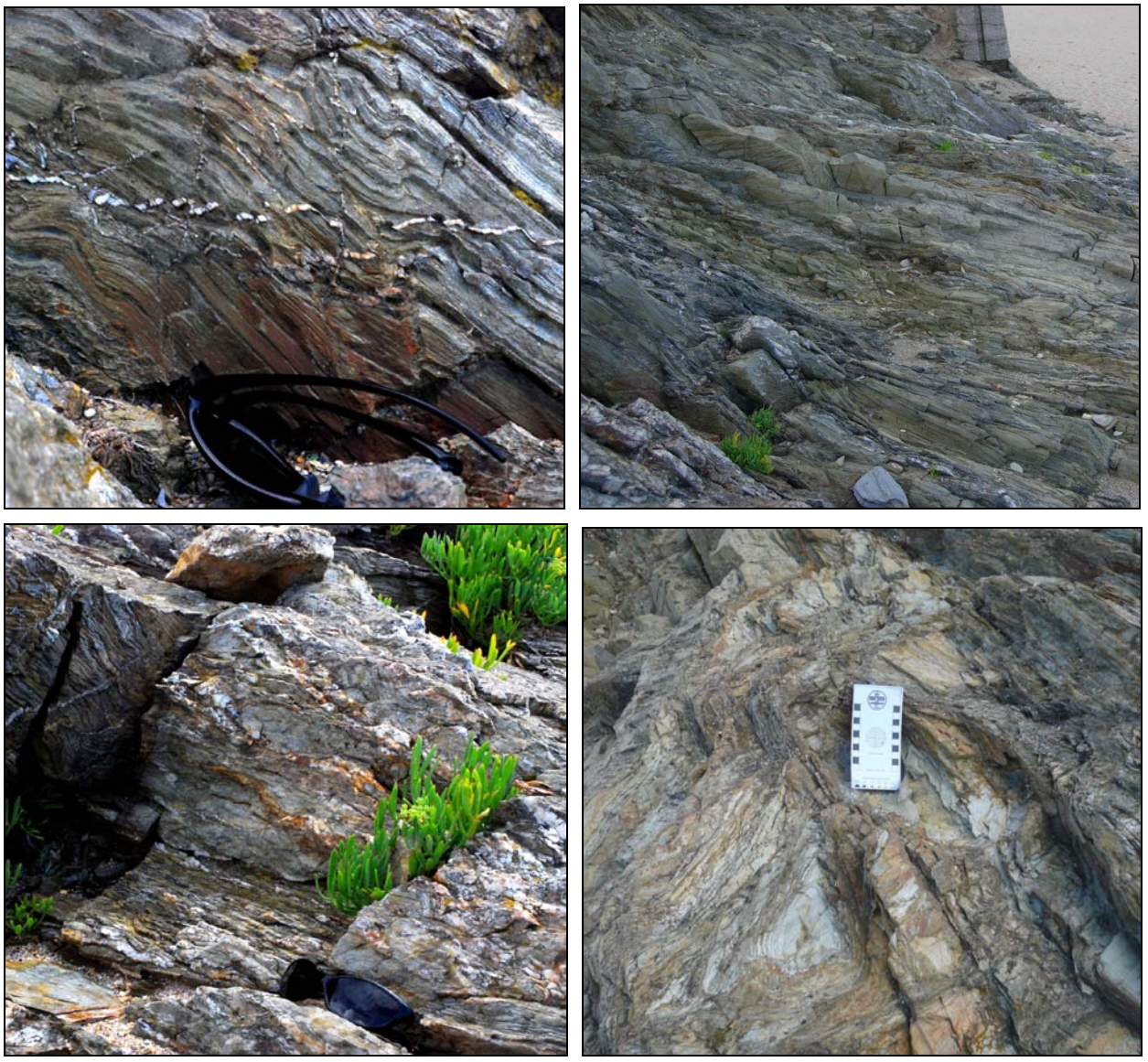
Approximate width at base of image (clockwise from top left) 1m; 0.75m; 2m and 0.25m.

Location	**5 Portscatho (SW879352)**
Geology	Portscatho Beds
Age	Mid Devonian
Lithological Characteristics	The Portscatho Beds are typified by dark sandstones with interbedded slates
Structural Characteristics	The sandstones and slates are thinly bedded.

Approximate width at base of image (clockwise from top left) 1m; 6m and 0.5m.

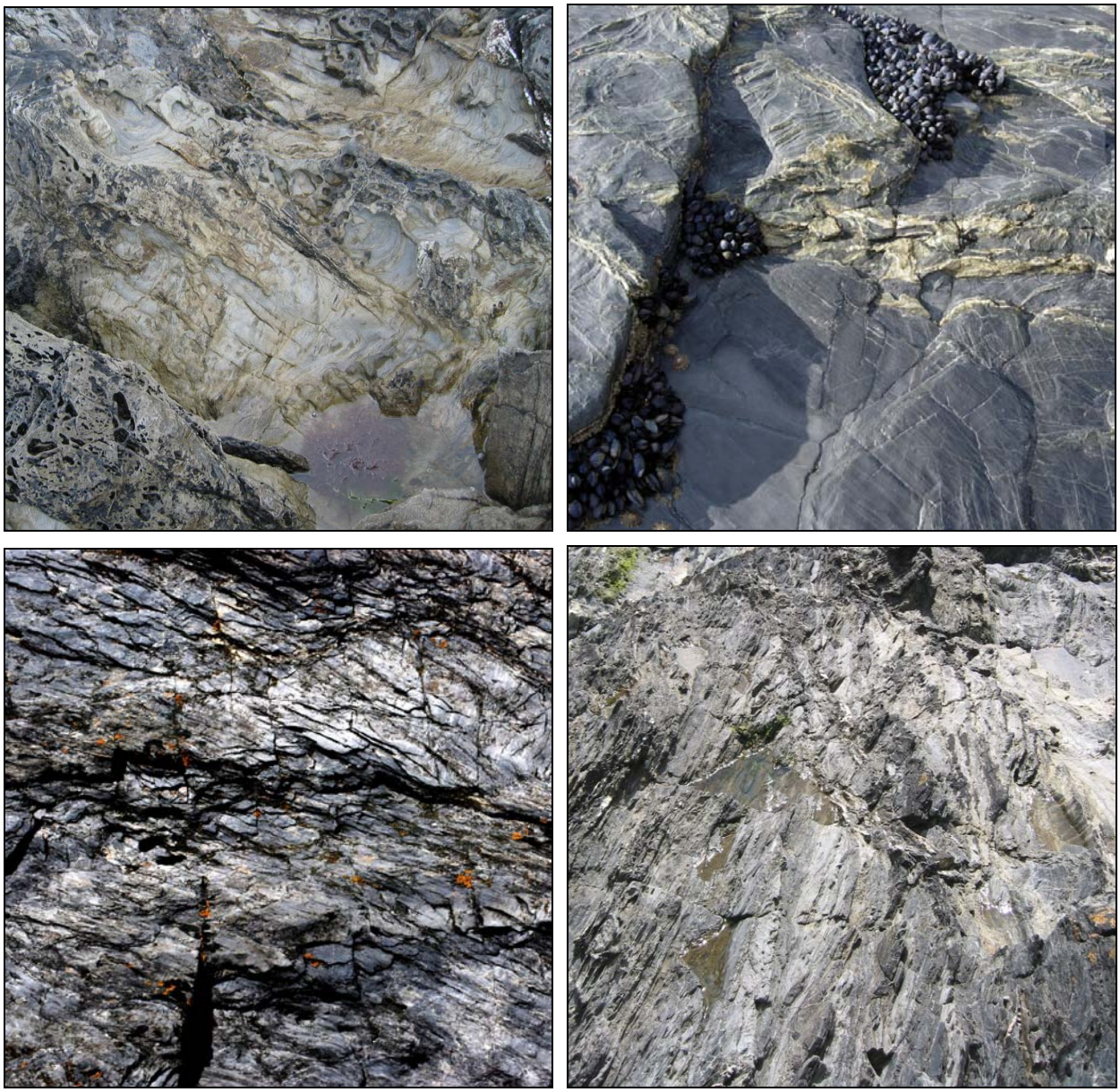
3.4 DEVONIAN SLATE

Location	**6 Porthleven (SW644241)**
Geology	Mylor Slate and Gramscatho Beds
Age	Devonian
Lithological Characteristics	The Mylor slate formation at Porthleven comprises grey green 'slaty' mudstone as the dominant lithology. Laminae of siltstone and distal turbidites are present. The quartz content is high and the mica content low. Red staining is present in localised areas.
Structural Characteristics	The interbedded mudstone and siltstone is thinly bedded with lower levels of deformation than that at Godrevy Point. In some areas the rocks are well-bedded with a 'blocky' nature.



Approximate width at base of image (clockwise from top left) 0.4m; 4m; 1m and 1.5m.

Location	**7 Godrevy Point (SW580433)**
Geology	Mylor Slate
Age	Late Devonian
Lithological Characteristics	Godrevy Point is characterised by large exposures of grey 'slaty' mudstone with thin interbeds of pale sandstone. A sharp contact between the mudstone and underlying sandstone is evident.
Structural Characteristics	Parasitic folding and multiple faulting episodes are displayed. The bedding dips at approximately 10^{o} East.



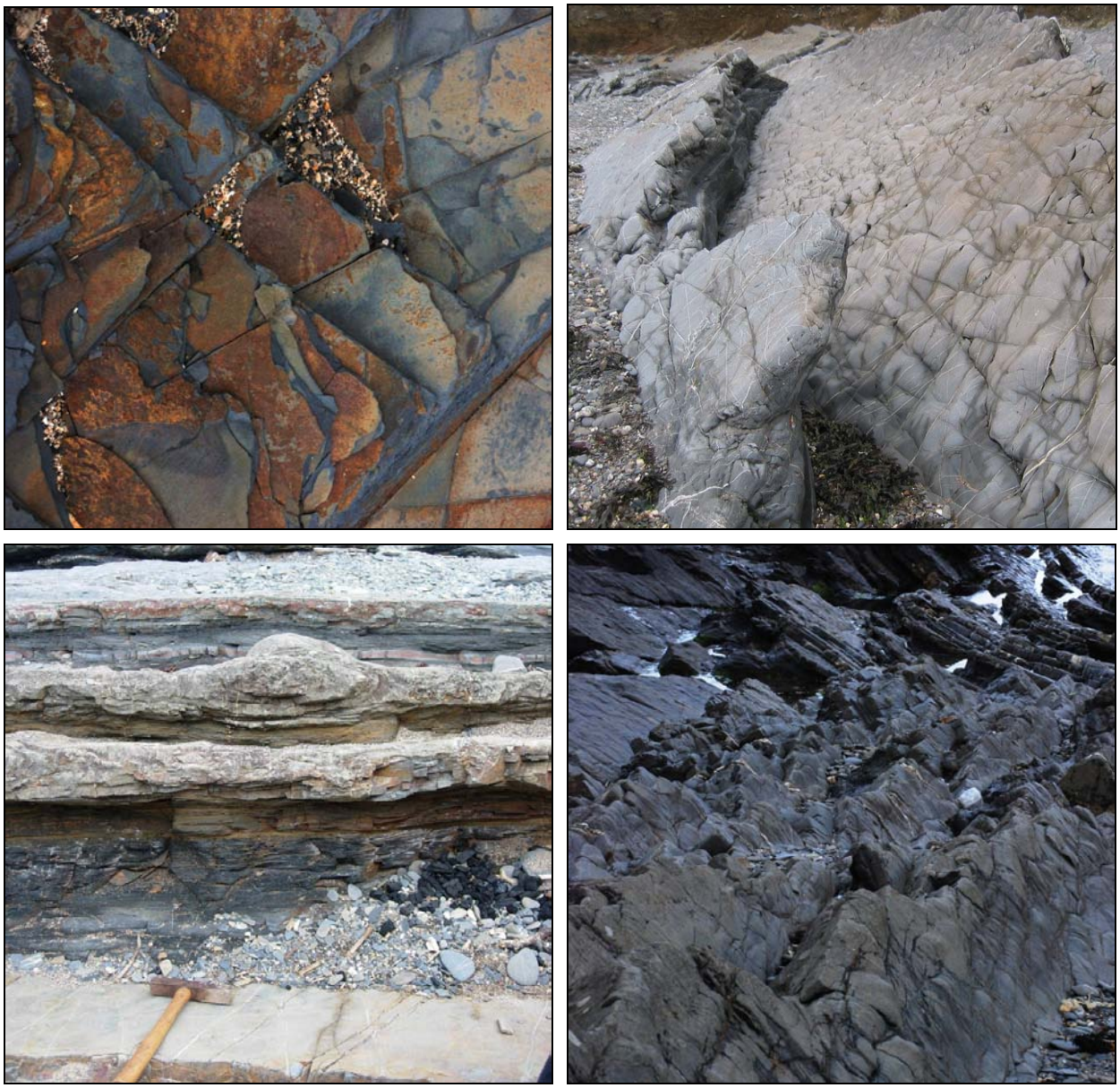
Approximate width at base of image (clockwise from top left) 0.75m; 0.5m; 1m and 1m.

3.5 CARBONIFEROUS MUDSTONE, SANDSTONE AND LIMESTONE

Location	**8 Boscastle (SX097916)**
Geology	Boscastle Formation
Age	Late Devonian/Early Carboniferous
Lithological Characteristics	Exposures of the Boscastle Formation are evident around the harbour. These rocks include black 'slaty' mudstones with thinly interbedded sandstones. Quartz content is high.
Structural Characteristics	Unlike their Devonian counterparts, two stages of deformation (rather than one) are shown. The Boscastle formation is also, in general, more resistant than the Devonian rocks.

Approximate width at base of image (clockwise from top left) 1m; 2m; 1.5m and 0.75m.

Location	**9 Crackington Haven (SX142969)**
Geology	Crackington Formation
Age	Late Carboniferous
Lithological Characteristics	Foreshore sections of dark gray shales and siltstones with thick sandstone pockets are displayed at Crackington Haven. Subordinate turbidities are present.
Structural Characteristics	Only one phase of deformation is displayed within the Crackington Formation. The rocks are characterised by steeply dipping inverted beds. Lode casts are present.



Approximate width at base of image (clockwise from top left) 0.3m; 1.25m; 1.5m and 1m.

Location	**10 Widemouth Bay (SS197024)**
Geology	Bude Formation
Age	Late Carboniferous
Lithological Characteristics	The Bude Formation at Widemouth Bay is comprised of discrete black marine mudstones and thickly bedded deltaic sandstones. In contrast to the Crackington Formation, siltstone is also present in the Bude Formation. Composite turbidite beds are also present.
Structural Characteristics	The mudstone and sandstones posses a discrete, linear or ribbed form. A lack of folding within these rocks suggests that they have a brittle nature.

Approximate width at base of image (clockwise from top left) 1m; 2.5m; 0.75m and 0.5m.

3.6 LAND'S END INTRUSION

Location	**11 Porthcurno (SW388222)**
Geology	Biotite Granite
Age	Late Carboniferous
Lithological Characteristics	The biotite granite is coarse grained with large crystals and large pebble inclusions. Areas of hydrothermal injection are also seen. Some alignment of the many phenocrysts (both normal and potassium feldspar phenocrysts) is evident.
Structural Characteristics	The rocks are castellated with mixed jointing directions. Both rounded and angular structures are displayed.

Approximate width at base of image (clockwise from top left) 0.3m; 1.5m; 0.1m and 1m.

Location	**12 Porth Nanven (SW355309)**
Geology	Biotite Granite
Age	Late Carboniferous
Lithological Characteristics	Coarse grained granite with potassium feldspar megacrysts is present at Porth Nanven. Fewer phenocrysts are evident here than at Porthcurno.
Structural Characteristics	As at Porthcurno, mixed jointing directions are displayed but levels of castellation are lower.

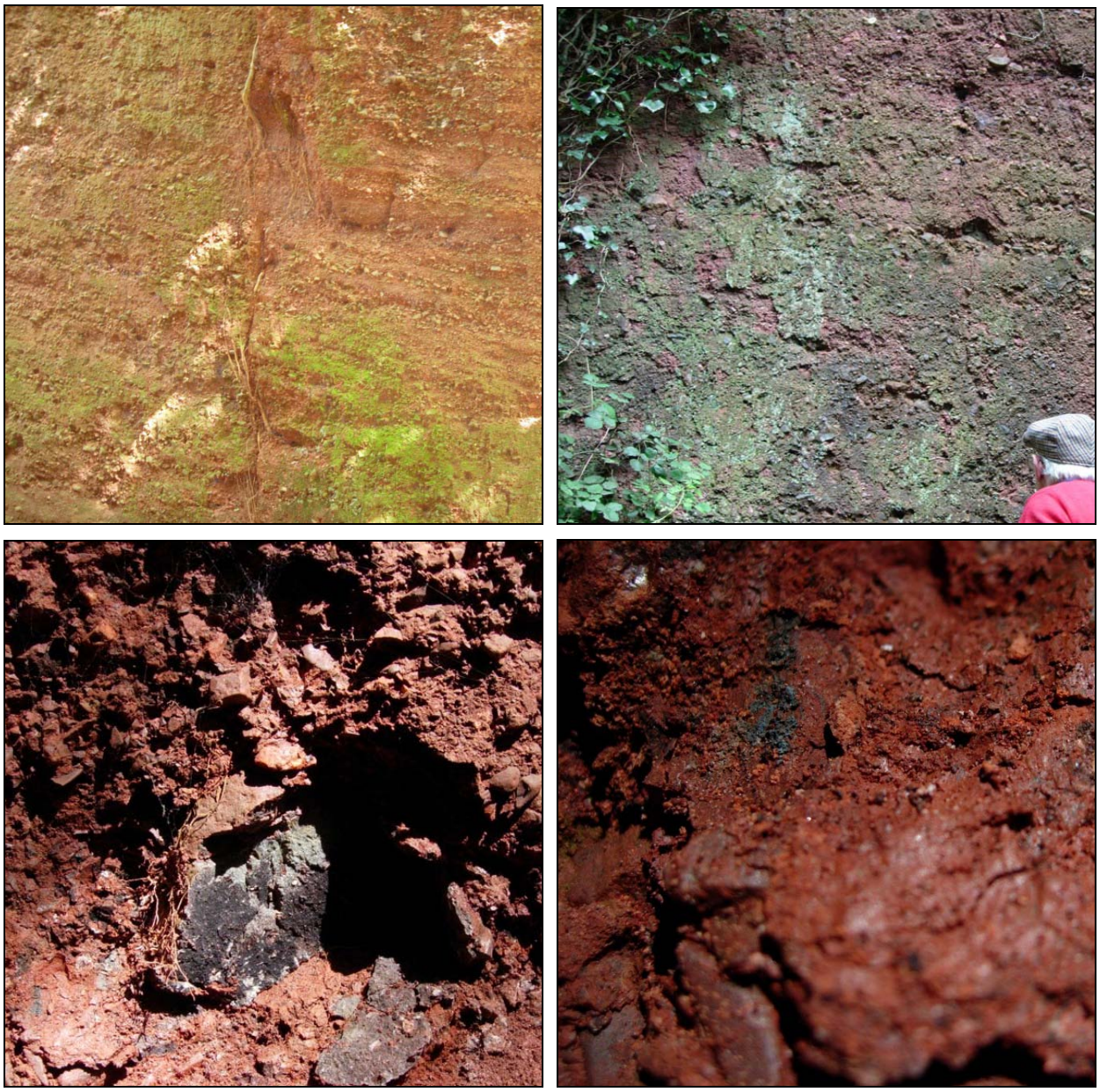
Approximate width at base of image (clockwise from top left) 1.5m; 3.5m; 0.1m and 4m.

3.7 PERMIAN AND TRIASSIC MUDSTONE, SANDSTONE AND SILTSTONE

Location	**13 West Sandford (SS811028)**
Geology	Bow Breccia and Knowle Sandstone
Age	Early Permian
Lithological Characteristics	Inland exposures of Bow Breccia and Knowle sandstone with associated volcanics are present at West Sandford. The background fluvial red bed sediments are suggestive of high energy, erosive environments. Areas of manganese oxates produce darker areas within the matrix. Volcanic ash and acid igneous debris are also present.
Structural Characteristics	The rocks are moderately well cemented and bedding is parallel, with an approximate dip of 12^{o}. The parallel bedding is interrupted by faulting.

No photos were collected at this site due to poor light conditions.

Location	**14 Cromwell's cutting (SS817003)**
Geology	Newton St Cyres Breccia
Age	Late Permian
Lithological Characteristics	Cromwell's Cutting reveals coarse facies of the Newton St Cyres Breccia. Mixed clasts including agglomerate, tuff and granite fragments are present within the dark red rocks. The presence of non-kaolinised feldspar suggests a lower energy provenance than that of the Bow Breccia and Knowle Sandstone, potentially a braided stream environment.
Structural Characteristics	The Newton St Cyres Breccia displays a lobate form which is not present in the other Breccias.



Approximate width at base of image (clockwise from top left) 2m; 2m; 0.05m and 0.15m.

Location	**15 Building site (SS817003)**
Geology	Creedy Park Sandstone
Age	Mid-Late Permian
Lithological Characteristics	Fresh cuttings at a building site reveal that the Creedy Park Sandstone is slightly cemented.
Structural Characteristics	The Creedy Park Sandstone has thin parallel beds with a ‘platy’ nature.

Approximate width at base of image (clockwise from top left) 0.1m; 0.25m; 0.15m and 0.25m.

Location	**16 Posbury Quarry (SX815977)**
Geology	Exeter Basalt
Age	Early Permian
Lithological Characteristics	The Exeter Basalt in Posbury Quarry is described as 'Pepperite', i.e. a basalt-sandstone mixture potentially produced through the interaction of moist sediment and volcanic activity. Quartz phenocrysts are in evidence and vesicles are infilled with carbonates, monmonilloroids and silica.
Structural Characteristics	The rock is characterised by a blocky form and grey colouring.

Approximate width at base of image (L-R) 3m and 3m.

4 Summary

- Exposures of 16 terrestrial rocks analogous to those populating the Cape Bank and Lizard offshore study areas were described using a combination of literature review and field investigation.
- Numerous small scale differences in rock characteristics can be seen in the terrestrial examples including colouring, phenocryst occurrence, grain size and degree of alteration. However, when using these descriptions to aid analysis of sidescan and multibeam data, structure is likely to provide the best evidence for distinguishing between rock types. It is therefore noted that relative relief, degree of rounding, orientation and dip of bedding and degree of deformation provide the most valuable distinctions.
- The terrestrial exposures presented herein will also be compared with photographic and video data collected during the offshore surveys.

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