Igneous Rocks of South-West England

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Northminster House,
Peterborough PE1 1UA.

Scottish Natural Heritage,
12 Hope Terrace,
Edinburgh EH9 2AS.

Countryside Council for Wales,
Plas Penrhos,
Ffordd Penrhos,
Bangor,
Gwynedd LL57 2LQ.

Preface

This volume illustrates some of the significant aspects of magmatic activity from Devonian (408 million years ago) to early Permian (270 million years ago) times in SW England. This period covers the progressive development of the Variscan mountain-building episode, from initial basin formation to final deformation and the subsequent development of a fold mountain belt – the Variscan Orogen. Both extrusive (volcanic) and intrusive (plutonic) rocks are found in the orogen, and chart the various stages of its magmatic development.

The sites described in this volume are key localities selected for conservation because they are representative of the magmatic history of the orogen from initiation to stabilization. Some of the earliest volcanic activity in the Devonian is represented by submarine basaltic and rhyolitic lavas developed in subsiding basins, caused by the attenuation of the existing continental crust. In some cases, extensive rifting and attendant magmatism produced narrow zones of true oceanic crust, whereas elsewhere basaltic volcanism is related to fractures in the continental crust at the margins of the basins. After the filling of the sedimentary basins, and their deformation caused by crustal shortening (late Carboniferous Period), further activity is manifested by the emplacement of the Cornubian granites and later minor basaltic volcanism in the early Permian.

Accounts of the constituent parts of this history have enriched geological literature from the nineteenth century onwards, and have contributed to the advancement and understanding of magmatic and tectonic processes. South-west England contains examples of the composition and emplacement of ancient ocean crust (ophiolites), the diversity and formation of submarine lavas, the emplacement of multiple granite intrusions and their effects on the surrounding rocks, and of the nature of economically important post-magmatic alteration processes and mineralization.

P.A. Floyd, C.S. Exley and M.T. Styles

Chapter 1

The igneous rocks of south-west England

INTRODUCTION AND SITE SYNTHESIS

The magmatic rocks of south-west England fall within the northern European Variscan fold belt; they are dominated by pre-orogenic basic–acid volcanics and post-orogenic granites, together with minor volcanics, that span the Devonian and Carboniferous systems. These major magmatic groups have played their part in the evolution of petrogenetic theory, but on a more limited scale than, say, the igneous rocks of the British Tertiary province, and generally relative to the development of the Variscan fold belt. For example, the small-volume, effusive volcanic rocks of Devonian–early Carboniferous age in south-west England were identified in the early European literature as representative of the so-called 'spilite–keratophyre geosynclinal association'; that is, the association of basic and acidic volcanics in a deep basinal setting. They have their temporal counterparts throughout the Variscan Orogenic Belt of Northern Europe and provided the scientific battleground for argument over the primary versus secondary origin of spilitic rocks (for example, Vallance, 1960; Amstutz, 1974), rocks which we now recognize as metamorphosed basalts.

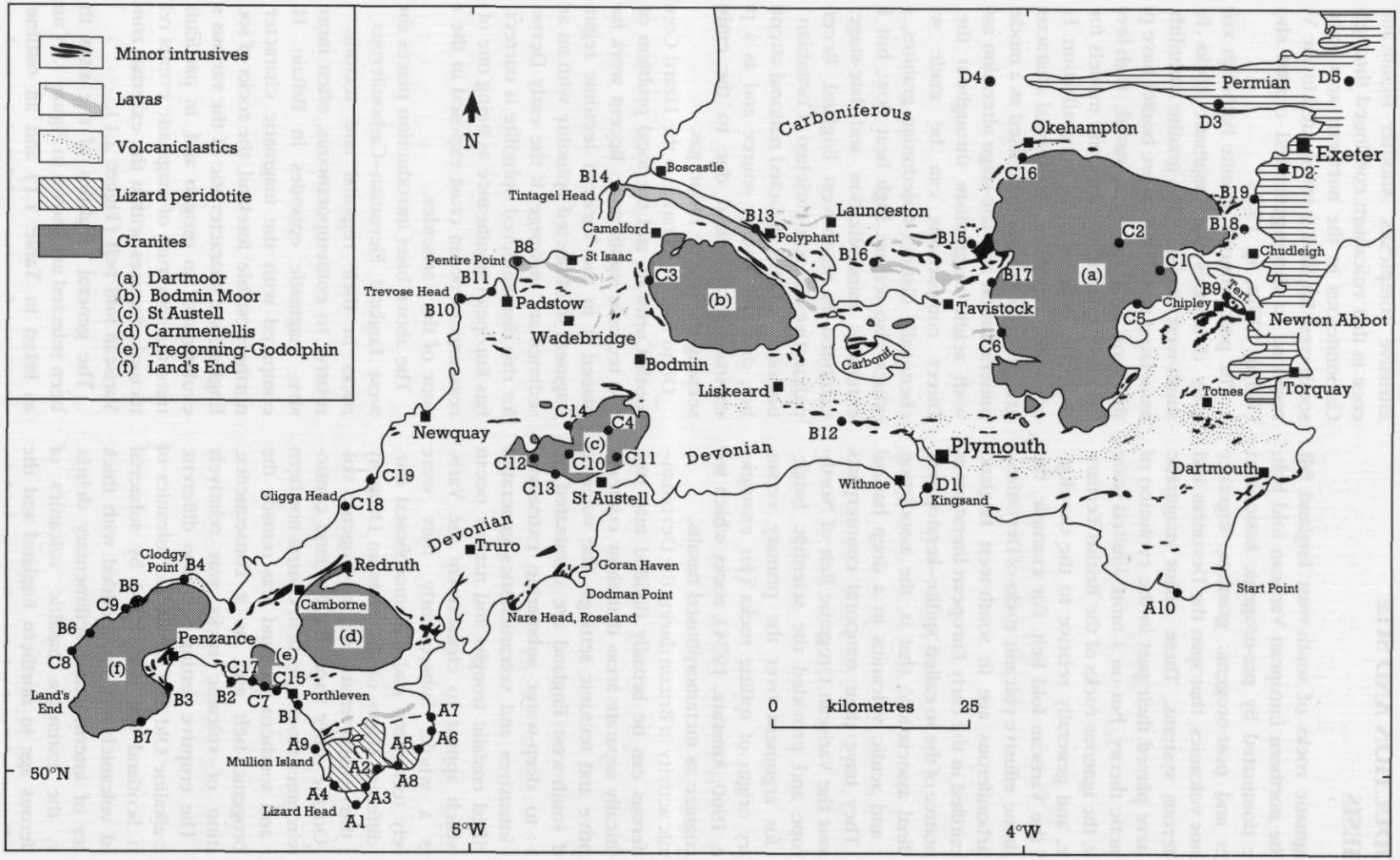
Volcanic activity in Britain during the Devonian–Carboniferous can be broadly divided into two geographically separate areas that show contrasting eruptive and tectonic settings. The volcanic rocks of south-west England are dominated by medium- to deep-water submarine extrusives, shallow intrusives and volcaniclastics generated within rifted ensialic troughs and narrow ocean basins which appear to characterize the Variscides as a whole. Subsequently, they were extensively tectonized and metamorphosed during the different stages of the Variscan Orogeny and are thus characteristic of pre-orogenic volcanism. On the other hand, the foreland continental environment to the north in central-northern England and southern Scotland was outside the active orogenic belt and, as a consequence, deformation of volcanic rocks was relatively limited. The eruptive setting was also different. The calc-alkaline Old Red Sandstone volcanics of southern Scotland are dominated by subaerial lavas and volcaniclastics interbedded with thick sequences of intermontane sedimentary debris. Similarly, the extensive basaltic volcanics of Carboniferous age in northern England and the Midland Valley of Scotland are characterized by subaerial lavas and shallow, but often thick, intrusive complexes. Another significant difference is that volcanism continued throughout the Carboniferous in the northern area, whereas in south-west England it terminated in the Viséan in response to thrust-generated crustal shortening (Floyd, 1982a, fig. 15.2).

The post-orogenic granite batholith volumetrically dominates the magmatic rocks found in south-west England. The granite batholith and its associated metalliferous ore bodies have provided the type area for fractionated, high-level, high heat-flow granitic terranes and models for hydrothermally induced zonal mineralization. From the economic viewpoint, the special character of the granite batholith has been used as a model for tin mineralization and late-stage alteration associated with acidic magmatism throughout the world. Direct comparisons can be made with the chemically distinct Caledonian granites, some of which also feature high heat flow, but lack the extensive mineralization and late-stage effects exhibited in south-west England. Recently the radioactive-element-enriched Cornubian granite batholith has also attracted national attention as a hot, dry rock energy source and as a potential environmental hazard due to the emission of seeping radiogenic radon gas.

Of no less importance is the Lizard Complex in south Cornwall, and the local problem of its age and tectonic significance. Recent work has firmly placed it in the Variscan tectonic regime, as a fragment of obducted ophiolite with an attendant sedimentary *mélange*. If the early Devonian age for this dismembered ophiolite is correct, then it has European significance as being one of the few remnants of ocean crust exposed in the external zone of the Variscides.

The above brief introduction places the south-west England Devonian–Carboniferous igneous rocks in their regional and tectonic context relative to contemporaneous, often more extensive, magmatic episodes in Britain. However, compared with the magmatic character of the northern 'stable' foreland, the rocks of south-west England are characteristic of the various stages of evolution of an orogen and, in particular, illustrate the spectrum of magmatic events relative to tectonic features within the external zone of the Variscan fold belt (Figure 2.1).

The general localities of the sites that have been selected are shown in Figure 1.1 (numbered as listed in Table 1.1) and an outline of the significant features exhibited by each group of sites is given below. Details of the spatial and


Minor intrusives
Lavas
Volcaniclastics
Lizard peridotite
Granites
(a) Dartmoor
(b) Bodmin Moor
(c) St Austell
(d) Carnmenellis
(e) Tregonning-Godolphin
(f) Land's End
N
Carboniferous
Permian
Devonian
Devonian
Carbonif.
Okehampton
Exeter
Launceston
Chudleigh
Tavistock
Newton Abbot
Chipley
Totnes
Torquay
Plymouth
Dartmouth
Withnoe
Kingsand
Liskeard
Bodmin
Wadebridge
Padstow
Camelford
Boscastle
Tintagel Head
Pentire Point
St Isaac
Trevose Head
Polyphant
Newquay
St Austell
Cligga Head
Truro
Redruth
Camborne
Penzance
Clodgy Point
Land's End
Porthleven
Goran Haven
Dodman Point
Nare Head, Roseland
Start Point
Mullion Island
Lizard Head
D4
D5
D3
D2
B14
B13
B8
B11
B10
B15
B16
B17
B18
B19
B9
C16
C2
C1
C5
C6
C3
C4
C14
C12
C10
C11
C13
C19
C18
B12
D1
A10
B4
B5
C9
B6
C8
B3
B2
C7
B1
C17
C15
B7
A7
A6
A5
A8
A9
A2
A4
A3
A1
0 kilometres 25
50°N
5°W
4°W

temporal location, emplacement environment and origin of the volcanic and plutonic rocks within the tectonic zones of the Variscan Orogen and the local geological framework of south-west England are given in Chapter 2.

Two interrelated criteria were used for the selection of sites in south-west England:

1. to provide a full stratigraphical coverage of different magmatic activity throughout the Hercynian fold belt;
2. to illustrate the special or unique petrological and chemical characteristics of different magmatic units and their petrogenesis.

This allowed the continuum of magmatic activity within a fold belt to be documented, as well as highlighting special features best displayed in this region relative to elsewhere in the United Kingdom. The justification for choosing these specific sites, rather than others showing similar features, often rested on a combination of adequate geological exposure, lithological freshness and accessibility.

The sites can be conveniently grouped into four main units (A–D) that roughly relate to stratigraphical age and major magmatic events within the Variscan. Some significant geological features exhibited by these units are summarized below:

Lizard ophiolite, *mélange* and Start Complex

The plutonic complex of the Lizard ophiolite includes the serpentinized peridotite, gabbro and basaltic dykes, together with heterogeneous acid–basic gneisses. As representatives of oceanic crust, these units play an important role in the interpretation of early Variscan basins in south Cornwall; they also provide evidence for subsequent northward obduction. Although a volcanic carapace to the ophiolite is not present in sequence, tectonically associated, metamorphosed lavas (now hornblende schists) chemically similar to mid-ocean ridge basalts are consistent with a Lizard ocean-crust model. Metamorphism and tectonism possibly occurred both in a suboceanic setting and during obduction. The metavolcanic greenschists of the Start Complex also exhibit mid-ocean ridge chemical features and may represent another tectonized segment of the early Variscan ocean floor in this region.

Figure 1.1 Simplified geological map of south-west England showing the distribution of magmatic rocks and the approximate location of sites described in the text (modified from Floyd, 1982b). Sites are numbered and grouped as in Table 1.1.

Pre-orogenic volcanics

This unit comprises various stratigraphically localized volcanic rocks which were erupted contemporaneously with basinal sedimentation. They range in age from Devonian to early Carboniferous, but culminated in late Devonian–Viséan times. Although they represent a bimodal basic–acid suite (the old 'spilite-keratophyre association'), the volcanics are dominated by basaltic pillow lavas and high-level intrusives of both tholeiitic and alkaline character. Basic and acidic tuffaceous volcaniclastics are also common throughout the Upper Palaeozoic. The volcanics invariably have been altered subsequent to consolidation and deposition, exhibiting secondary assemblages indicative of the prehnite–pumpellyite and lower greenschist facies of metamorphism.

Cornubian granite batholith

The culmination or late stages of the Variscan Orogeny were marked by the emplacement of the Cornubian batholith at the end of the Carboniferous. This body is often interpreted as the product of the melting of sialic crust induced by continent–continent collision. Although predominantly a two-mica calc-alkaline granite, the batholith is composed of multiple intrusions, ranging in age from about 300 to 270 Ma and encompasses a number of highly fractionated acidic members including Li- and F-rich variants. Late-stage alteration effects are well displayed and include extensive tourmalinization, greisenization and kaolinization. The granite was also the source of the hydrothermal Sn–W mineralization as well as the heat engine for associated Cu–Pb–Zn–Fe–As deposits within the margins of plutons and their aureoles.

Group A sites:
Lizard ophiolite and mélange

A1 Lizard Point
(SW 695116 - SW 706115)
A2 Kennack Sands
(SW 734165)
A3 Polbarrow-The Balk
(SW 717135 - SW 715128)
A4 Kynance Cove
(SW 684133)
A5 Coverack Cove-Dolor Point
(SW 784187 - SW 785181)
A6 Porthoustock Point
(SW 810217)
A7 Porthallow Cove-Porthkerris Cove
(SW 798232 - SW 806226)
A8 Lankidden
(SW 756164)
A9 Mullion Island
(SW 660175)
A10 Elender Cove-Black Cove, Prawle Point
(SX 769353 - SX 769356)

Group B sites:
Pre-orogenic volcanics

B1 Porthleven
(SW 628254 - SW 634250)
B2 Cudden Point-Prussia Cove
(SW 548275 - SW 555278)
B3 Penlee Point
(SW 474269)
B4 Carrick Du-Clodgy Point
(SW 507414 - SW 512410)
B5 Gurnards Head
(SW 432387)
B6 Botallack Head-Porth Ledden
(SW 362339 - SW 355322)
B7 Tater-du
(SW 440230)
B8 Pentire Point-Rumps Point
(SW 923805 - SW 935812)
B9 Chipley Quarries
(SX 807712)
B10 Dinas Head-Trevose Head
(SW 847761 - SW 850766)
B11 Trevone Bay
(SW 890762)
B12 Clicker Tor Quarry
(SX 285614)
B13 Polyphant
(SX 262822)
B14 Tintagel Head-Bossiney Haven
(SX 047892 - SX 066895)
B15 Brent Tor
(SX 471804)
B16 Greystone Quarry
(SX 364807)
B17 Pitts Cleave Quarry
(SX 501761)
B18 Trusham Quarry
(SX 846807)
B19 Ryecroft Quarry
(SX 843847)

Group C sites:
Cornubian granite batholith

C1 Haytor Rocks area
(SX 758773)
C2 Birch Tor
(SX 686814)
C3 De Lank Quarries
(SX 101755)
C4 Luxulyan (Goldenpoint, Tregarden) Quarry
(SW 054591)
C5 Leusdon Common
(SX 704729)
C6 Burrator Quarries
(SX 549677)
C7 Rinsey Cove (Porthcew)
(SW 593269)
C8 Cape Cornwall area
(SW 352318)
C9 Porthmeor Cove
(SW 425376)
C10 Wheal Martyn
(SW 003556)
C11 Carn Grey Rock and Quarry
(SX 033551)
C12 Tregargus Quarries
(SW 949541)
C13 St Mewan Beacon
(SW 985534)
C14 Roche Rock
(SW 991596)
C15 Megiliggar Rocks
(SW 609266)
C16 Meldon Aplite Quarries
(SX 567921)
C17 Praa Sands (Folly Rocks)
(SW 573280)
C18 Cameron (Beacon) Quarry
(SW 704506)
C19 Cligga Head area
(SW 738536)

Group D sites:
Post-orogenic volcanics

D1 Kingsand Beach
(SX 435506)
D2 Webberton Cross Quarry
(SX 875871)
D3 Posbury Clump Quarry
(SX 815978)
D4 Hannaborough Quarry
(SS 529029)
D5 Killerton Park
(SS 971005)

Post-orogenic volcanics

Shortly after consolidation of the batholith and regional uplift, a post-orogenic volcanic episode began in the late Carboniferous–early Permian. This comprised both suprabatholithic acid volcanism fed by late granite-porphyry dykes, and mafic extrusives and intrusives related to fault-bounded troughs. The latter group include various lamprophyres which often characterize the last stages of magmatic activity, apparently associated with granites of continental origin.

Table 1.1 List of GCR igneous rock sites in south-west England (see Figure 1.1 for locations)