Igneous Rocks of South-west England (IGN-SW-E)

Block Description

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Introduction

The GCR sites selected for this GCR Block represent the magmatic rocks of south-west England that fall within the northern European Variscan fold belt (**see Variscan Structures of South-West England (VAR-STR-SW)**); they are dominated by pre-orogenic volcanic rocks and post-orogenic granites, together with minor volcanic rocks, that span the Devonian and Carboniferous systems (from 417 to 292 million years ago, Ma).

Volcanic activity in Britain during Devonian–Carboniferous time 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 intrusive rocks and volcaniclastic rocks generated within rifted ensialic troughs and narrow ocean basins that 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 volcanic rocks of southern Scotland (**see Old Red Sandstone Igneous (Silurian and Devonian Volcanic Rocks) (ORS-IGN))** are dominated by subaerial lavas and volcaniclastic rocks interbedded with thick sequences of intermontane sedimentary debris. Similarly, the extensive basaltic volcanic rocks of Carboniferous age in northern England and the Midland Valley of Scotland (**see Carboniferous - Permian Igneous (C-P-IG)**) 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 Visean in response to thrust-generated crustal shortening.

The post-orogenic granite batholith volumetrically dominates the magmatic rocks found in south-west England.

Of no less importance is the Lizard Complex in south Cornwall, a fragment of obducted ophiolite with an attendant sedimentary melange. 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 regional setting –Variscan Orogeny

A large part of the geology of Europe from Poland to Iberia is represented by the broad, sinuous, roughly E–W-trending Variscan fold belt which has affinities with the Appalachian Belt on the other side of the Atlantic Ocean and the Uralide Belt in Russia.

The Variscan Orogen of northern Europe consists of a series of Ordovician to Carboniferous rift-generated basins, separated by metamorphosed crystalline ridges, which were progressively closed by the northward migration and subsequent collision of African Gondwanaland with northern Baltica. The Variscan orogenic belt is divided into a number of tectonic zones separated by major thrusts, ranging from the northern (external) Rhenohercynian zone to the (internal) Saxothuringian and Moldanubian zones of central Europe. The Rhenohercynian and Saxothuringian zones include basinal sedimentary sequences and volcanic rocks indicative of initial rifting and later synorogenic sandstones heralding subsequent closure. Although much of the basic–acid volcanism of these basins is typical of rifted continental crust, basaltic lavas with mid-ocean ridge (MORB) chemical characteristics are present and suggest that narrow oceans floored by oceanic crust were generated. Between these two zones in central Europe is the Mid-German Crystalline Rise largely composed of pre-Devonian magmatic and high-grade metamorphic rocks that have their counterpart in Armorica as the crystalline Normannia High. The Moldanubian zone is

dominated by largely Precambrian magmatic and metamorphic rocks overprinted by Variscan tectonometamorphic events.

Essential to the Variscan story is the staged closure of the sedimentary basins by subduction of narrow oceanic segments and northwards-directed thrusting from late Ordovician through to Carboniferous time, such that many sequences are thrust bound and parautochthonous or allochthonous in character. In contrast to the general northwards convergence and progressive closure throughout much of the Palaeozoic, the basinal region that formed in the Rhenohercynian zone was not only late in development, but rapidly closed – opening in early Devonian and closing by the end of late Devonian time.

The magmatic rocks covered by this GCR Block are all within the external Rhenohercynian Zone of the Variscides, some of which have features in common with their counterparts in the rest of the orogen. The sedimentary and volcanic record of the Rhenohercynian Zone reflects an early Devonian rifting event that was rapidly followed by late Devonian to late Carboniferous crustal shortening that produced stacks of northwards-converging nappes and accompanying low-grade regional metamorphism. Relatively high-level, post-orogenic, granite magmatism is a common feature of this zone.

Basic–acidic volcanism is a characteristic of all Variscan tectonic zones, although volcanic sequences are generally dominated by basalts (‘spilites’) with minor trachytes and rhyolites (‘keratophyres’ and ‘quartz keratophyres’). Early Devonian rhyolites and late Devonian–Dinantian basalt pillow lavas and intrusives in south-west England have their temporal counterparts throughout the Rhenohercynian and Saxothuringian Zones, although the Moldanubian zone also exhibits late Dinantian calc-alkaline andesite-dominated volcanism. Throughout the Rhenohercynian zone most of the basalts are incompatible element-enriched, intraplate tholeiites and alkali basalts – the latter of which are particularly characteristic of south-west England. However, Middle and Upper Devonian basalts within stratigraphically restricted melange sequences have chemical affinities to MORB and, together with the Lizard ophiolite and Start Complex in Cornubia, they provide evidence for the existence of Rhenohercynian oceanic crust. Another chemical characteristic that appears to be a common feature of the basalts within the Rhenohercynian (and possibly Saxothuringian) Zones is the change in degree of incompatible-element enrichment from the Devonian to the Carboniferous. This is probably a reflection of the change from generally depleted MORB-type basalts in mid-late Devonian rift zones to the more enriched intraplate basalts of late Devonian and early Carboniferous age on the margins of basins.

As far as the Variscan granites are concerned, all the tectonic zones contain granitic massifs, many of which include types resembling those of the Cornubian batholith. In addition to older pre-Variscan intrusives and metamorphics, two or three distinct intrusive phases are found.

GCR site selection

Two inter-related 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.

The sites can be conveniently grouped into four main networks (A–D) that roughly relate to stratigraphical age and major magmatic events within the Variscan Orogeny.

(A) Lizard ophiolite melange and Start Complex

The plutonic complex of the Lizard ophiolite includes the serpentinized peridotite, gabbro and basaltic dykes, together with heterogeneous acid–basic gneisses that 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. 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.

(B) Pre-orogenic volcanic rocks

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–Visean times. Although they represent a bimodal basic–acid suite (the old ‘spilite-keratophyre association’), the volcanic rocks 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 volcanic rocks invariably have been altered subsequent to consolidation and deposition.

(C) 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 Period.

(D) Post-orogenic volcanic rocks

Shortly after consolidation of the batholith and regional uplift, a post-orogenic volcanic episode began in late Carboniferous–early Permian times, comprising both suprabatholithic acide volcanism and mafic intrusive and extrusive rocks related to fault-bounded troughs.