CHAPTER II
REGIONAL GEOLOGY
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Cornwall is underlain dominantly by sedimentary strata of Devonian and Carboniferous age cut by four principal granite intrusions. In the extreme south, a complex of metamorphic and basic igneous rocks form the Lizard Peninsula (not considered further in this account). It is the granites (Bodmin Moor, St Austell, Carnmenellis and Land's End) and associated dykes ('elvans' and lamprophyres) and alteration products (greisen) which have provided the majority of the stones considered in this account (Fig. 5, p. 11). Prior to this study, only one sedimentary rock (Breage 1) was thought to have been used for pre-Norman sculpture, but a sandstone carving has now also been identified at Pelynt. In addition, volcanic rocks from the Tintagel Volcanic Formation have been used for Boscastle 1, Tintagel 2 and Davidstow 1.

The underlying 'solid' geology of Cornwall is indicated in Fig. 4. However the 'solid' strata are in places covered by thick, and/or locally extensive, 'drift' deposits such as peat, alluvium and blown sand. These 'drift' deposits are omitted from Fig. 4.

METHODOLOGY

All the carved stones in the present area have been examined, *in situ*, using a hand lens. As the stones could not be 'hammered' to produce a fresh surface, examination depended partly on the vagaries of preservation and location. It means that some stones could not be properly examined, for example those with a heavy overgrowth of lichen (Lanivet 3, Tintagel 3, Wendron 3). The above-mentioned lens has an in-built graticule which allows the size(s) of the constituent grains to be determined fairly accurately. However, as most of the granites are coarse-grained with some crystals up to 10 cm long, many of the measurements of the constituents were commonly made by ruler.

In the following account, although the sedimentary rocks constitute only a small percentage of the sculptures (compared to the granites), the strata are described in ascending geological sequence, with the granites, which are the youngest rocks and which are intruded into the sedimentary rocks, described last.

The grain-size terminology for the sedimentary rocks is based on Wentworth (1922) which distinguishes five sandstone categories: very fine 0.032–0.125 mm, fine 0.125–0.25 mm; medium 0.25–0.5 mm; coarse 0.5–1.0 mm; and very coarse 1.0–2.0 mm. The term 'granule' refers to grains between 2 and 4 mm; 'pebbly' refers to clasts/grains >4 mm.

The carved stones in the present area derived from sedimentary rocks are all detrital siliciclastic sandstone (that is, rocks in which more than 50% of the grains are clastic fragments derived from the breakdown of pre-existing siliceous rocks). All have a high percentage (95% or more) of silicate grains, of which translucent quartz is dominant. White, opaque feldspars are present in some samples, but at their maximum occurrence, only form 1% of the grains. The grains are held together by naturally occurring cements. The cement of the Cornish examples is always silica. As all the sandstones are grain-supported (that is, the constituent grains are in contact), the cement forms only a minor part of the whole rock. The qualification of the term 'sorting' as used herein does not follow the strict geological definition as no grain size analysis was undertaken. 'Well sorted' means that most of the grains are of approximately the same size; 'poor' is the opposite, with a wide variation in grain size; 'moderate' falls between the two preceding definitions.

Volcanic rocks from the Tintagel Volcanic Series include both igneous rocks (lava: Boscastle 1) and sedimentary tuffs and tufaceous shale (Tintagel 2 and Davidstow 1).

The colours and their numeric reference used to

describe the carved stones are taken from the Rock-Color Chart produced by the Geological Society of America, 1963. As many of the stones are outside, or have only recently been brought inside, the surface colour has commonly been modified by air-borne pollutants, or the stones are heavily lichen encrusted. Consequently, the colour of a sculptured stone rarely can be determined with accuracy unless the stone has been accidentally damaged or scratched.

STONE TYPES USED FOR THE SCULPTURES

As mentioned above, the stone types used for sculpting in Cornwall are derived principally from two sources: granites and associated rocks (elvans, lamprophyres and greisens) and sedimentary rocks (and associated volcanic rocks) (see Fig. 5). The sedimentary rocks used for sculptures are described in approximate stratigraphical order. Geological formations may contain other beds than those of building (or sculptural) stone quality; for example, the sandstones of the Carboniferous Crackington Formation can be too hard for sculptural or fine stone work. All the carved pre-Norman, non-volcanic, sedimentary stones in the present district are quartz sandstones of fluvial origin. The constituent sandstone grains are sub-angular to sub-rounded and are mostly medium-, or medium- to coarse-grained.

DARTMOUTH AND MEADFOOT GROUPS

The oldest rocks, those of the Devonian Dartmouth and Meadfoot Groups, crop out across the central tract of Cornwall from Newquay on the west coast to just north of Mevagissey on the south coast and from there eastwards to Plymouth and beyond.

The lower, Dartmouth Group, consists dominantly of grey, green and purple slates with some interbedded sandstones, conglomerates and pyroclastic rocks, especially in the east of the outcrop. As no early carved stone is attributed to this unit, it is not considered further.

The succeeding Meadfoot Group comprises a lower Bovisand Formation (formerly the Meadfoot Beds) and an upper Staddon Formation. The Bovisand Formation consists of up to 1300 m of dominantly medium to dark grey slaty mudstone with thin sandstone beds and sporadic limestone beds. Packets of quartzitic sandstone occur in the area from Pelynt eastwards towards Plymouth and are known as the Lower and Upper Long Sands Sandstone Members. These two units consist dominantly of sandstone in sedimentary cycles with mudstone, siltstone and subordinate limestone. The Long Sands Sandstone Members have been quarried for walling stone in the Looe area and may have provided the stone for Pelynt 1, although the Staddon Formation cannot be ruled out. The Pelynt cross-head consists of pale yellowish brown (10YR 6/2), poorly sorted, clast-supported, quartz sandstone. The sub-angular to sub-rounded quartz clasts are pale orange and range in size from 0.3 to 2.5 mm, but are mostly in the range 0.4 to 0.6 mm.

The Staddon Formation comprises up to 500 m thick, medium to thick beds (1–4 m) of fine- to medium-grained sandstone, thickening and coarsening upwards, and with thin interbedded grey mudstone and siltstone. It may have been the source of Breage 1, but this would involve transport over a distance of at least 50 km.

TAMAR AND GRAMSCATHO GROUPS

The Tamar and Gramscatho Groups have a wide outcrop on either side of the Dartmouth and Meadfoot Groups. They consist dominantly of mudstone and slate, but with some interbeds of limestone and sandstone. None of these lithologies from this group has been used for the early Cornish sculpture described in this volume. However, an important unit high in the sequence is the Roseland (formerly Meneage) Breccia which crops out on the northern side of the Lizard Peninsula. It is an olistostrome composed of a chaotic mixture of enormous blocks (up to 1.5 km across) of various rock types formed by gravity sliding or slumping. Of the various rock types incorporated in the olistostrome, locally 'grits' and fine conglomerates occur. The only stone in the present area which may be derived from the Roseland Breccia is the sandstone cross and base at Breage. However, the published descriptions of the sedimentary rocks incorporated in the Roseland Breccia do not appear to match either the colour or hardness of this sandstone. It is suggested above that the Staddon Formation could have been the source of the Breage 1 cross, but in view of the transport involved (over 50 km), this seems unlikely.

TEIGN VALLEY GROUP

The Teign Valley Group consists dominantly of shale and slate, with subordinate beds of sandstone, limestone and chert. The Tintagel Volcanic Formation, which occurs approximately in the middle of the group, extends eastwards from Tintagel on the north side of Bodmin Moor as far as Launceston, where it caps

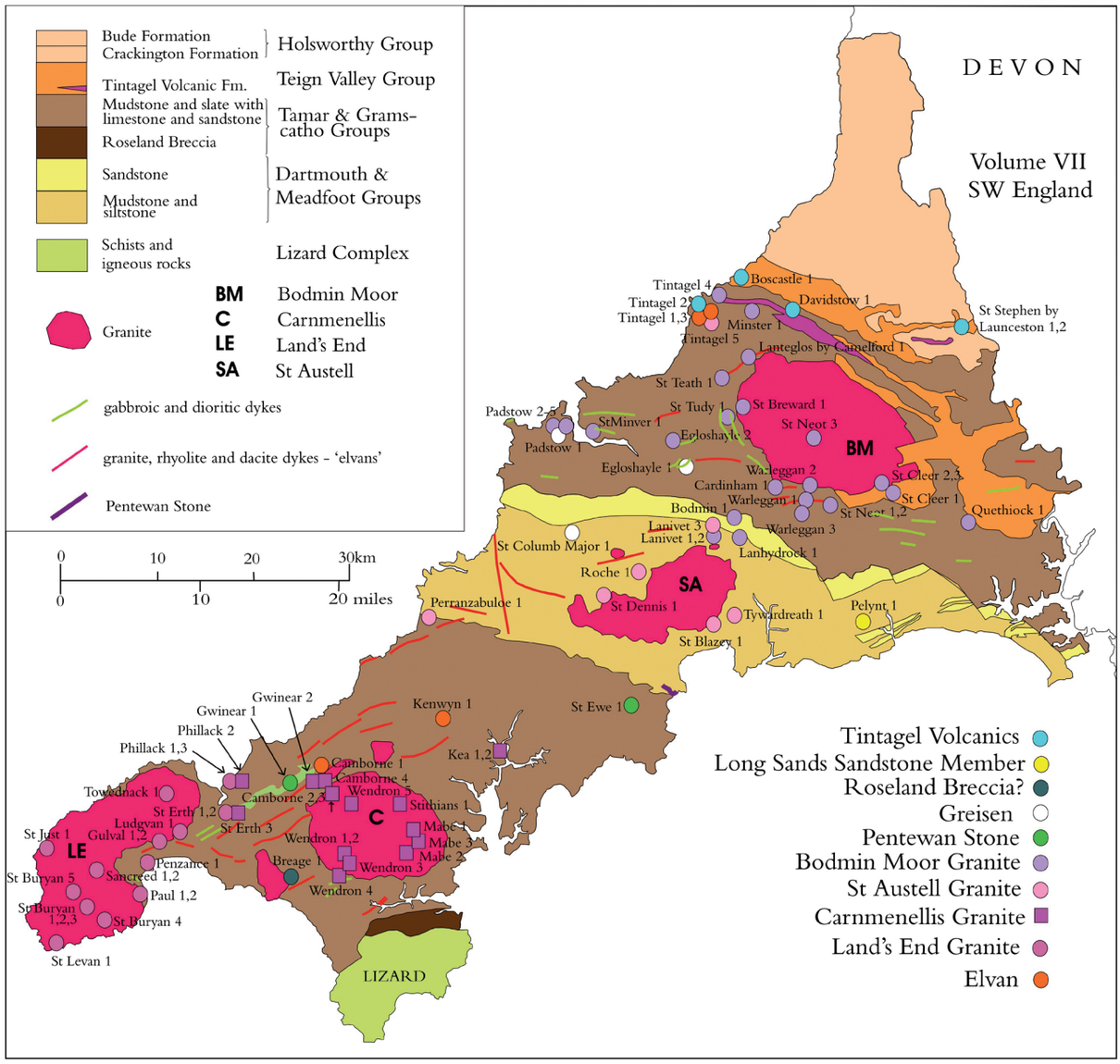

FIGURE 5
The solid geology of Cornwall, with the distribution of stone types used for early medieval sculptures in Cornwall

the hill on which the castle is built. The formation, which is about 90 m thick in the type area and up to 200 m thick in the Davidstow area, generally comprises highly sheared, well-bedded, interbedded shales, tufaceous shales (as seen in the Davidstow 1 cross-base), and fine- to coarse-grained, vesicular, tuffs (St Stephen by Launceston 1 and 2) and lavas, with agglomerates well developed around Trevalga and Davidstow. The tuffs are commonly interbedded with marine sediments. Typical agglomerate contains rounded fragments of vesicular lava with the vesicles flattened parallel to the apparent bedding (Tintagel 2). The vesicles are commonly filled with pink calcite, but this readily weathers out.

HOLSWORTHY GROUP

The Holsworthy Group, which crops out from just north of Bude northwards and eastwards to the Devon border, comprises the Crackington Formation below and the Bude Formation above. Both formations are commonly intensely folded. The Crackington Formation, up to 340 m thick, consists of dark grey to black mudstone up to 0.3 m thick, interbedded with thin siltstones and hard sandstones generally between 0.3 and 1 m thick. The ratio of sandstone to shale is about 3:1. However, the sandstones are too hard to provide a good, carvable, source of stone, although they do provide suitable stone for walls, buildings, roads and tracks. This, together with the distance from any sources of granite, may in part explain the absence of any pre-Norman sculpture in this area. The succeeding Bude Formation, up to about 1300 m thick, comprises sandstone and mudstone in approximately equal proportions. The sandstones, although overall similar to those in the Crackington Formation, are not quite so hard, and occur in groups up to 20 m thick, but the individual beds are rarely more than 1 m thick. The sandstones are greyish green when fresh, but weather buff-brown and become more friable, and hence are more easily carved; they provided the stone for the early Norman font at Morwenstow, for example.

GRANITES

Four great cupolas of granite, part of the Cornubian batholith, extend south-westwards across Cornwall: Bodmin Moor, St Austell, Carnmenellis, and Land's End, but with a number of smaller bosses (Carn Brea, Carn Marth and Tregonning-Godolphin on the north and west of the Carnmenellis Granite: see Fig. 4). The granites, emplaced as magmas, generally have a fairly sharp contact with the surrounding sediments, although some veining by fine-grained granite is common. Generally, the granites give rise to rugged tors surrounded by moorland or rough pasture. The granites from each area are generally of an overall similar chemical and mineralogical composition, but they do vary in detail. Granites are composed of varying proportions of quartz (usually about 30%), feldspar (both orthoclase and plagioclase: usually about 54%) varying from 1–2 cm (Carnmenellis and Bodmin Moor granites), up to 20 cm long (Land's End and St Austell granites), and a dark coloured mica (biotite) of up to 6%. Secondary white mica is locally present (up to 6%) with tourmaline as a common, visible, accessory mineral (up to 8 mm long). Topaz, zircon, rutile, apatite and andalucite occur in smaller, varying proportions, and are used to subdivide the granites (see Selwood *et al.* 1998, fig. 7.1).

Macroscopically, following Dangerfield and Hawkes (1981), granites are subdivided by a combination of the grain size of the matrix (fine <1.0 mm; medium 1.0–2.0 mm, and coarse >2.0 mm) and the size and proportion of the potassium feldspar megacrysts. The megacrysts are termed small if less than 15 mm, and large if greater than 15 mm. The abundance of megacrysts is described as: abundantly megacrystic > 10%; moderately megacrystic > 5–10%, and poorly megacrystic < 5%. More refined subdivisions of the granites based on petrology and geochemistry are possible, but this is rarely an option when dealing with carved stones. Dangerfield and Hawkes (1981, 118–19) recognise seven broad types of granite (although there are overlaps):

- Coarse-grained megacrystic granite
- Coarse-grained poorly megacrystic granite
- Coarse-grained megacrystic granite with small megacrysts
- Medium-grained non-megacrystic lithium-mica granite
- Medium-grained granite with few megacrysts
- Medium-grained granite with very rare megacrysts
- Fine-grained granite, both megacryst rich and megacryst poor varieties.

The majority of the Cornubian granites are coarse-grained. Coarse-grained, megacrystic, granite occurs on the eastern side of the St Austell Granite, and forms the bulk of the Land's End Granite. Coarse-grained, poorly megacrystic, granite forms the middle part of the St Austell Granite (heavily kaolinised) and in a small area in the centre of the Land's End Granite. Medium-grained granites are confined to a small area

on the western side of the St Austell Granite, and to the central part of the Carnmenellis Granite. Small patches of fine-grained granite occur within the Bodmin Moor, Carnmenellis, and Godolphin Granites (all poorly megacrystic), as well as the St Austell and Land's End Granites (abundantly megacrystic). The largest area of fine-grained, patchily megacrystic, Land's End Granite occurs north-west of Ludgvan (SW 49 34).

A zone of contact metamorphism varying from 1 km wide (Carnmenellis and Bodmin Moor granites) to 7 km wide (St Austell Granite) extends from the contact of the granites and surrounding rocks.

The granites usually host, or are associated with, metalliferous deposits, which have long been exploited. The granites are noted for their exceptionally high content of the radioactive elements Potassium, Thorium and Uranium.

The granites have been widely worked as a building stone both in Cornwall and outside the county (Eddystone Lighthouse, Blackfriars Bridge in London, British Museum), as well as for troughs, gateposts, walling stone etc. The crushed granite makes an excellent aggregate.

It is the durable granites with their widespread distribution which have provided most of the stone for pre-Norman sculpture in Cornwall. However, because of their relatively coarse texture, the level of detail on these monuments is generally not as good as it is on some of the finer grained stones. The coarse-grained Bodmin Moor Granite with its relatively small megacrysts (usually between 1 and 2 cm long), has been the granite most widely used (22 stones), with the generally coarser-grained, and more altered, St Austell Granite the least used (6 stones). Indeed, it is remarkable that the distribution of early sculpture in Cornwall is predominantly focussed around the two granite areas of Land's End and Bodmin Moor. This raises the question of whether the easy availability of suitable stone in these areas encouraged the creation of stone monuments, or whether further examples of early sculpture once existed elsewhere which have simply not survived. Carvings of sandstone may have been more easily broken up or become so highly eroded that their original nature has become lost. The very recent chance discovery of the sandstone cross-head at Pelynt and the extremely eroded character of the cross at Breage (Breage 1) may suggest that the latter suggestion is the correct one.

INTRUSIVE DYKES

There are two principal types of dykes in Cornwall: elvans (quartz porphyry) and lamprophyres (ultra-potassic igneous rocks).

Elvan is a west country name for a quartz porphyry. Elvans commonly cross cut the coarse-grained granite varieties and extend into the surrounding sediments. They consist dominantly of quartz and feldspar megacrysts (up to 3 cm), and, rarely, mica set in a fine-grained, commonly banded, rhyolitic matrix. It has been used for both a building and walling stone. Early sculptures using elvans are Camborne 1, St Ewe 1, Gwinear 1, and Tintagel 1.

Camborne 1 is carved from the Tucking Mill Elvan, a rock characterised by large feldspar megacrysts, which occurs in near vertical dykes, trending roughly east to west; these dykes vary in width from a few centimetres to tens of metres.

The cross-base at St Ewe and the cross now at Lanherne (Gwinear 1) both have a similar, distinctive, lithology resembling Pentewan Stone (a felsic dyke of granitic composition). It is an easily worked stone, which consists of a glassy matrix forming about 50% of the rock, studded with clear quartz crystals ranging in size from 0.3 to 1.5 mm. Most of the quartz crystals have fallen out leaving distinctive small holes. Pentewan Stone has been widely quarried and was in common use for building and sculpture from Norman times on. It was used in the construction of medieval churches, including Lostwithiel, Mevagissey, St Austell, and St Columb Major, as well as more recently in Antony House. In addition, a fifth- or sixth-century inscribed memorial of Pentewan Stone in Tregony church (Okasha 1993, no. 66) is one of the earliest carved stones to use this material.

Tintagel 1 constitutes a third type of elvan and consists of small (up to 0.2 mm by 10 mm) white feldspar megacrysts (forming 20% or less of the rock) and clear quartz grains up to 3 mm across, but only a few scattered grains of white mica, set in a fine-grained, rhyolitic matrix.

ALTERATION OF THE GRANITES

There are three main types of alteration: tourmalinisation, kaolinisation (ultimately resulting in china clay, of which the St Austell Granite has been most affected, particularly the western two-thirds) and greisening. These types overlap and are not always distinct from one another. However, it is only the last, greisening, which is relevant to this study. Greisening involves the replacement of the feldspars by aggregates of quartz (dominant) and white mica. In the most striking examples (Egloshayle 1, St Columb Major 1

and Padstow 1), the rock resembles a medium-grained quartz sandstone, with the original quartz phenocrysts up to 4 mm across having the appearance of small pebbles. All the stones used in the above pieces are essentially similar and consist of sub-angular quartz grains ranging from 0.3 to 0.7 mm across, but are mostly between 0.5 and 0.6 mm across, with a few of clear quartz up to 4 mm. A few scattered flakes of white mica (muscovite) are present as plates up to 1 mm across and intergrown with the quartz. A few scattered, relic, clasts of white feldspar may be present. The exact source of these three very similar stones is not known, but it is probably from the western end of the St Austell Granite. Greisen is much more easily worked than granite so it may well have been deliberately selected for these monuments. It has been used in various forms and from various sources from Bronze Age times and was popular for the manufacture of querns and bowls.

SOURCING AND TRANSPORTING THE STONES

From Fig. 5 it can be seen that the distribution of the stones used for early Cornish sculpture broadly follows the outcrop of the strata from which they are presumed to be derived. This would suggest that most carved stones have not been transported far from their source rock. This is clearly shown by those stones derived from the Tintagel Volcanic Formation (Boscastle 1, Davidstow 1 and Tintagel 2). The coarse-grained Land's End Granite has only been used away from the peninsula at nearby Phillack and St Erth (but see remarks about Perranzabuloe 1 below). Similarly, the coarse-grained St Austell Granite has only been used in five pieces around the edge of the granite outcrop, except, surprisingly, for Tintagel 5, carved from the distinctive and exceptionally coarse-grained Luxullianite, which has been transported at least 25 km from the eastern side of the St Austell Granite. St Piran's Cross (Perranzabuloe 1) is carved from a coarse-grained, megacrystic granite that could have come from either the Land's End Granite or the St Austell Granite (probably the latter), but whichever granite it is derived from, it involves a minimum transport of 30 km. The finer-grained, much more widely used, Bodmin Moor Granite has rarely been transported far, except for Padstow 2 and 3 whose stone was transported at least 20 km westwards. It is curious that Bodmin Moor Granite was used for Lanivet 3, in preference to St Austell Granite, since the latter would have been a closer source and was used for carving Lanivet 1 and 2.

Pieces of uncertain provenance include the three similar-looking greisens used for Egloshayle 1, Padstow 1 and St Columb Major 1. The St Austell Granite is the most likely source for these stones. The exact provenance has not been determined, but in the cases of Egloshayle 1 and Padstow 1 this may have involved transportation of up to 18 km. Similarly, the source of Breage 1 (possibly a local stone incorporated in the Roseland Breccia, or possibly more widely travelled and derived from the Staddon Formation) and Gwinear 1 (possibly Pentewan Stone) are uncertain.