# Farnham Geological Society

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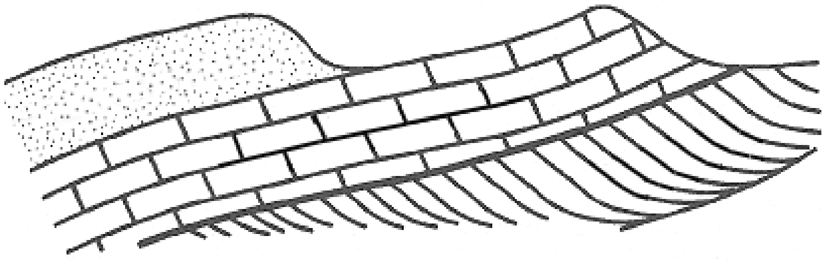
*Farnhamia farnhamensis*



*A local group within the GA*

Vol. 16 No.3

## Newsletter

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## List of contents

## Editorial

This issue would be enormous if we included all the material I have received (all of it contributed by members). Namely: Peter Forsyth's paper; summaries of monthly meetings, including John Stanley's and my talks at the July meeting, and the extensive contributions from the 20-odd members who attended Graham's excellent field trip to Jersey. I feel it is important to give due space to all these contributions so we will have to leave some articles for next time – the February 2014 issue. The biggest problem has been the number and size of all the photos and it is difficult to reduce them without losing a lot of definition.

## Komatiites - ultramafic volcanic rocks

### Summary of July 2013 lecture given by John Stanley, Member FGS

Komatiites are ultramafic, mantle-derived, volcanic rocks. They have low $SiO_2$, low KO, low $Al_2O_3$ and high to extremely high MgO. They were named for their type locality along the Komati River in South Africa.

True komatiites are very rare and essentially restricted to rocks of Archaean age, with few Proterozoic or Phanerozoic komatiites known (although high-magnesian lamprophyres are known from the Mesozoic). This restriction in age is thought to be due to secular cooling of the mantle, which may have been up to 500°C hotter during the early to middle Archaean (4.5 to 2.6 Ga). The early Earth had much higher heat production, due to the residual heat from planetary accretion, as well as the greater abundance of radioactive elements. The chemical composition of komatiites is compared below with that of picrites and meimechites.

| | |
|---|---|
| Picrite - | $Na_2O+K_2O > 1$ % |
| Komatiite - | $Na_2O+K_2O < 1\%$ and $TiO_2 < 1\%$ |
| Meimechite - | $Na_2O+K_2O < 1\%$ and $TiO_2 > 1\%$ |

*Editor's Note:*

Picrites (olivine-rich basalts containing essential olivine, plagioclase and clinopyroxene) are often considered Mg-rich parental magmas representing direct partial melts of the mantle that have been affected by little crystal fractionation. They can be either olivine tholeites or alkali basalts. Picrites are relatively rare basalts since the majority of basaltic magmas experience storage in crustal magma chambers and removal of olivine by settling (IC).

Meimechites are highly magnesian alkaline lavas, which comprise olivine and some chromite in a matrix of titanian clinopyroxene, ilmenite, altered glass, and, usually, biotite. The very high MgO contents in the meimichites are interpreted to be due to melting from a great depth, as much as 200 km, either in the lowermost continental lithosphere or in the underlying asthenosphere (SD).

**References**

- IC Imperial College Rock Laboratory – https://www2.imperial.ac.uk/earthscienceandengineering/rocklibrary/viewglossrecord.php?gID=00000000064.
- SD Science Direct http://www.sciencedirect.com/science/article/pii/0024493795900098).
- Photo by C. Nicollet from Google 'komatiite images' internet webpage.

*John Stanley*

## Abereiddi Bay revisited

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Abereiddi Bay lies on the north-west coast of Pembrokeshire and at its north end is an abandoned slate quarry. After its closure in 1914 it was flooded by the owners who cut a channel to the sea, thus forming the small harbour illustrated in Fig.l. As can be seen, it has very limited access for other than small boats.

Figure 1

Figure 2

The 'slate' is of the Llanvirn series of the Ordovician, but it was not fully metamorphosed during the considerable volcanic activity of mid-Ordovician times. It thus remains a shale in which the cleavage that was imposed lies closely parallel to, or on, its bedding plane. Because of this such fossils as the 'paper thin' graptolites shown in Fig. 2 have been preserved, whereas they would have been destroyed if those mechanisms that cause slaty cleavage on other planes had operated. The importance of the graptolites lies in their abundance, and the limited range in time of both genera and species, which, combined with their wide geographical distribution, makes them of particular use to stratigraphical geologists.

On one working face of the quarry a number of the original shot holes could still be seen. The bedding plane orientation of the exposed rock was roughly horizontal, as revealed by the exfoliation that had occurred over the one hundred years since the quarry was abandoned. The vertical faces, as indicated in Fig.3, were remarkably planar, indicating that there must have been joints present in the rock, as any other form of planar weakness was unlikely.

This was later proved as no planar cracking parallel to a recognised joint face could be produced on a selected specimen. Furthermore, a microscopical examination of the same material confirmed that there had been no structural change such as might have been produced by any of the several forms of schistosity.

Sir Charles Lyell in his treatise on Geology has much to say on the subject of joints. He quotes Professor Sedgewick: " .. joints are distinguished from slaty cleavage in this; that the rock intervening between two joints has no tendency to cleave in a direction parallel to the plane of the joints, whereas a rock is capable of indefinite sub-division in the direction of slaty cleavage".

Sir R.Murchison is also quoted: " .... (joints) are natural fissures which often traverse rocks in straight and well determined lines .... they afford to the quarryman the greatest aid in extraction of blocks of stone ... they must have resulted from one of the last changes superinduced on the sedimentary deposits"

Lyell himself has something to say on the origin of joints: " ..... such joints are supposed to be analogous to the partings which separate volcanic and plutonic rocks into cuboidal and prismatic masses .. On a small scale we see clay and starch when dry split into similar shapes; this is often caused by simple contraction, whether the shrinking be due to the evaporation of water, or to a change of temperature".

The general view seems to persist that with sedimentary rocks shrinkage causes fissures capable of growing to complete failure when the rock experiences an external load. Such defects might be isolated and small, but would have to be co-planar to produce the flat fractures observed. It is only in cases where shrinkage fissures happen to have been later penetrated by mineral deposits that one can be really sure of their presence. It may be that they do not always exist as it is reasonable to suppose that at the drying out stage in the rock's history not all of the shrinkage stress was released by cracking. Thus it would only need some augmentation of this internal stress by an external load, particularly one of the magnitude to be expected from firing, to cause fracture.

Figure 3

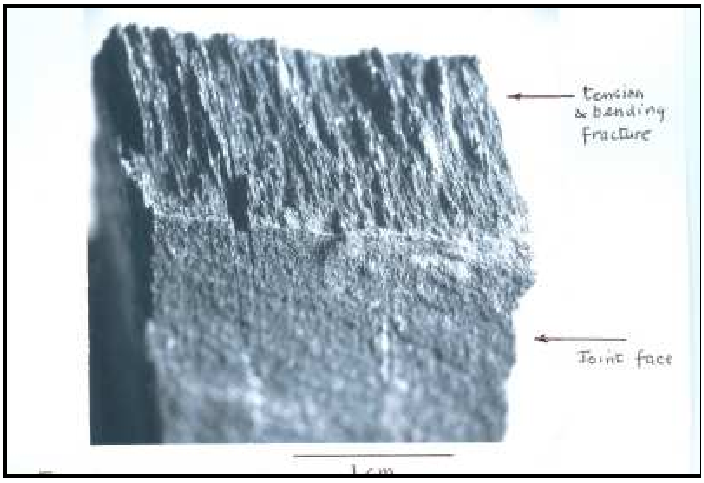

Figure 4

There are still features about these joints that need further consideration. Fig. 4 shows the surface texture of a joint and on the same specimen a test fracture in tension and bending. Both fractures have some contributing bedding plane separation, but that of the joint is much less than the other. In the case of tension and bending there has been considerable shear separation of the bedding planes, thus representing a high energy fracture.

The question is why does the shrinkage stress behave differently in this respect? One answer might be that when shrinkage occurred the material was structurally different to its present state, and this would be a reasonable assumption. A further factor might be the way that the shrinkage crack grew as the material dried out. This would have been very slow and at right angles to the bedding plane. All of the evidence is that tensile cracks growing in this direction deflect only slightly onto the bedding plane, thus explaining the relative smoothness of the joint face.

Turning back to the graptolites and the shale that now enclosed them. This started as a deep marine sediment in the Welsh basin of Ordovician times (490-443 Ma) that was hardened by compression and heat from upheaval and extensive volcanic activity, and the 'tuning fork' variety *Didymograptus murchisoni* is particularly associated with the Abereiddi rocks.

Forty years ago when this specimen shown in Fig. 2 was found, the beach was littered with shale fragments containing graptolites, but not so now. Nevertheless, exposed specimens can still be seen on the rock faces on the southern end of the beach, although it should be noted, this area is an SSI and the rocks must not be attacked!

*Peter Forsyth.*

# FGS field trip to Jersey – 21 to 27 April 2013

**Contributions by all on the trip**

## 1. Introduction

Jersey has a long coastline and a very large tidal range consequently there is excellent exposure around the coast, however inland the geology is only exposed in the odd quarry and along valley or lane edges – consequently the bulk of the trip was spent on the beaches and cliffs.

The Channel Islands (together with Brittany and Normandy) form part of the Cadomian Belt of the North Armorican Massif and probably formed part of an offshore island arc similar to modern day Indonesia. The exact location of Jersey within the Cadomian terrane at this time is uncertain due to the large scale wrench faulting which has affected the area.

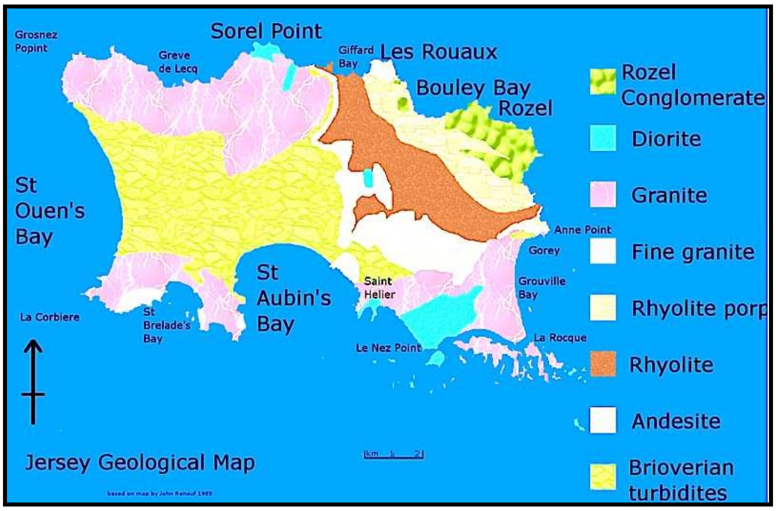

Fig. 1: Simplified Geological Map of Jersey

The rocks shown on the map are those of the Cadomian/Brioverian terrane:

- Cadomian plutonic rocks (granites/granodiorites /diorites) dated as Late Precambrian to Lower Paleozoic (ca. 570Ma to 426Ma);
- Extrusive rocks (rhyolites/andesites/ ignimbrites) and associated agglomerates of a similar age;
- Sedimentary sequences - Jersey Shale (late Precambrian) which outcrops across the island and Rozel Conglomerate (Lower Paleozoic) which overlies the volcanics.

These form the ‘foundation’ of the island and are overlain by Pleistocene loess deposits and cut by occasional Tertiary dykes.

Paleoproterozoic basement gneisess (2.2-2.5Ga) are present in N France below the Cadomian rocks but are not exposed in Jersey.

The overall structure of Jersey and location of the basic rock types noted above is relatively simple (see Fig. 1). Granite plutons form the NW, SW and SE ‘corners’ of the island, whilst the Brioverian volcanics outcrop around the NE corner. The granites are connected and continue beneath the entire island; the surface of the granite subcrop forms a ‘valley’ which dips towards the SW and is at its deepest below St Ouen’s Bay. Many properties use boreholes for water and the boreholes penetrate to the surface of the granite.

The Brioverian sediments overlie the granites and would outcrop across most of the interior were it not for the cover of the Pleistocene loess deposits which form a ca. 2m thick blanket on the hill tops and on which the famous ‘Jersey Royals’ are grown and the beautiful Jersey cows graze.

It is impossible to cover every aspect of the geology and every corner of the island, so the following discussion concentrates on the most interesting aspects of the geology seen during the week. The rocks fall into (and are described below under) three main categories: igneous plutons and dykes; igneous volcanics and agglomerates; Brioverian sediments. But Jersey has a great many archeological sites and these are also discussed.

## 2. Plutonic Bodies

The three main plutonic bodies are similar in outcrop forming semicircular complexes.The NW and SE complexes comprise both basic and acidic rock types whilst the SW is purely granitic.

**The SW Granite** forms a semicircular ‘ringed’ complex of three distinct granites: –

- the oldest is a fine grained but porphyritic granite in a narrow central ring, the La Moye Granite;
- the next oldest is a pink coarse grained granite with large xenoliths, the Corbiere Granite, and
- the youngest of the three rings is the Beau Port Granite, a fine grained appenitic granite.

**The NW Granite** is well exposed at Le Pulec and L’Etacq and quarried at Ronez. Access to the quarry was not available so the nearby outcrops at Sorrel Point and Groznez were briefly examined in icy, gale force NE winds.

Our visit to Le Pulec gave us a good view of the pink granite of the NW Igneous Complex (480-438 Ma) and its junction with the older Jersey Shale (580-540 Ma) (Fig. 2). The hardiest of the group waded through and over a mountain of seaweed to examine the junction of the two formations. Several granite dykes extruded from the margin, cutting into Jersey Shale. The granite is coarse grained, comprising grey glassy quartz, feldspars, some hornblende and biotite (Fig. 3); near the margin was a vein of sphalerite and other sulphate minerals. The vein appeared to run along a possible fault and was probably due to hydrothermal activity (Fig. 4). Attempts to mine this area proved uneconomic.

The grey Jersey Shale Formation had been metmorphosed into a narrow aureole of hornfels, spotted with cordierite, was locally deformed and sedimentary structures lost. Much of the deformation within the Jersey Shale was taken up by the zone of faulting to the W of the contact.

Fig. 2: Junction of NW Igneous granite and Jersey Shale at Lt Pulec.

Fig.3: NW Granite, Le Pulec

Fig. 4: Sphalerite/iron dolomite vein in the NW granite intrusion

**The SE Igneous Complex** is the most complex and most interesting of the three plutons, it is the well exposed from La Motte (Green Island) in the W to La Roque in the E. This Complex shows the diversity and age relations of the rock types within the 'Granite' ranging from gabbro to diorite to granodiorite and true granite with late stage pegmatite and aplite veins and is discussed in more detail.

The coarse-grained granite has large pink feldspars and is well exposed around the breakwater at La Rocque. Detailed features include very finely crystalline aplite veins and patches of large intergrown crystals of quartz and feldspar. The main interest however, is the basic and intermediate igneous rock complex exposed in the beach rocks further W at Le Hocq and La Motte. Here it is believed that the oldest rock, the post-Cadomian gabbroic rock, has been affected by the intrusion of later granite to form intermediate diorite. This may have occurred by the intrusion of granite and physical mixing and/or by the action of metasomatic fluids raising the $SiO_2$ content and converting the dark basic gabbroic rock into black and white intermediate diorite (Fig. 5). The result is a very wide variety of localised features, with almost every rock surface showing a different feature.

In places, there angular dolerite fragments, separated by diorite channels or veins (?stoping) and elsewhere, rounded dolerite fragments with diffuse contacts occur (?assimilation); further diorite occurs as darker patches, sometimes as very subtle 'shadow' xenoliths. There appear to be few chilled margins suggesting that the rocks were at a similar temperature at the time of intrusion or fluid penetration. Elsewhere it looked as though 'globules of basalt' were caught up in a granitic melt (Fig. 6).

Fig. 5: Assimilation of gabbro by granite fluids

Fig. 6: 'Globules' of basalt magma in granitic melt.

Fig. 7: Laths of amphibole

The patches of appinite, a striking pink rock with light feldspathic groundmass, show large prismatic hornblende crystals 2-3cm long (Fig. 7). The diorite showed spotted concentrations of porphyritic dark hornblende. Possible eye-like structures were seen where concentrations of large quartz and feldspar crystals grew inwards into what was probably a void with an associated rim of smaller dark crystals of hornhblende. There were also examples of layering in the dolerite on a 30cm scale. In this case, darker melanodolerite graded upwards into lighter leucodolerite. It was clear that the more basic rocks were the older and the granitic rocks the younger. Low grade regional metamorphism generated patches of epidote.

### 3. **Dykes**:

Younger than the plutonic rocks are an impressive number of dykes. Three main types exist: basaltic dykes are common, of several ages, orientations, and form swarms with sharp boundaries and may become wider or narrower, bifurcate or die out altogether. The E-W or ENE-WSW swarms are of Cadomian / Paleozoic age (the main Jersey Dyke Swarm), whilst the N-S are of Tertiary age.

In the SE Igneous Complex, both acidic and basic dykes occurred, showing multiple cross cutting relationships and showing the complex relationships between the 'more basic' bodies and the 'more acidic' bodies. One complex dyke had a granitic centre, another, porphyritic dyke, was seen with orange feldspars.

Later minor displacement of the dykes is common. The violence of the granitic intrusion is shown by Figs. 8 and also in Fig. 9, where it appears that the granite dykes and basaltic dyke intrusions were multiphase and appeared to be close in age. This particular dyke showed *gabbro/diorite rock intruded by a granite dyke with sheared ?basaltic margin then brecciation of the margin of the granite dyke and annealing with a basaltic magma. Then further faulting and displacement with finally a very late stage doleritic dyke of the Tertiary dyke complex.* The granite dykes, of multiple phases of intrusion, are of Cadomian/Paleozoic age; whilst the granitic aplite veins and pegmatites (Fig. 10) represent the last phase of granite intrusion.

A third type of dyke is present – the lamprophyre dykes. These are common but do not occur in swarms, they often have basaltic margins and more alkaline centres. One mica lamprophyre dyke had been faulted by a small tear fault showed prevalent phenocrysts of biotite mica giving a sparkly effect to the dark green groundmass of the intrusion which consists largely of ferro-magnesian minerals such as amphiboles and olivine. The fine grained nature of the chilled margins provide evidence for the rapid cooling of the dyke on contact with the surrounding rhyolite (Fig. 11).

The series of individual dyke intrusions were a result of post Cadomian orogenic crustal extension and dated as 480-427Ma.

Fig. 8: Angular bodies of diorite within granite near margin of the SE complex demonstrate explosive nature of the granite intrusion.

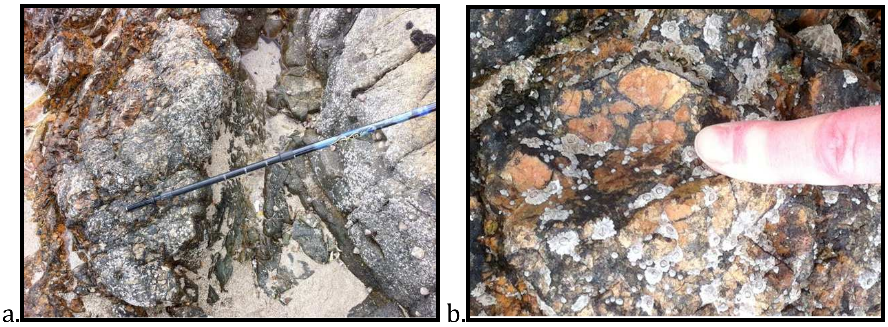

Fig. 9: a. Gabbro/diorite rock intruded by granite dyke with sheared basaltic margin then b. brecciation of the margin of the granite dyke and annealing with a basaltic magma. Then further faulting and displacement with finally a very late stage doleritic dyke of the Tertiary dyke complex.

Fig. 10: Aplite veins and pegmatites at La Roque

Fig.11:Lamprophyre dyke, Giffard Bay

### 4. **Extrusive Volcanic Rocks**

The volcanic rocks of Jersey are dominantly andesites and rhyolites. In Giffard Bay, adjacent to Bouley Bay, volcanic deposits of rhyolites, ignimbrites and agglomerates of the Bouley Rhyolite Formation outcrop. The rhyolites are a grey to brown colour and display a variety of textures including flow banding, brecciation and a nodular appearance caused by the formation of spherulites. The constituent minerals are too small to identify in hand specimen but rhyolite, as the fine grained equivalent of granites, will comprise quartz, feldspars and mica. The spherulites here form discontinuous bands and range in size up to 10mm in diameter. They consist of a white mineral - quartz or feldspar or possibly others. Some of the largest spherulites were seen on the path up Les Hurets hill, above the beach occurring (Fig. 12) as bands alternating with flow banded rhyolites. The spherulites grow within the rhyolite and appear as radiating crystals often showing concentric growth rings. They grew during cooling conditions as some grew across bands and others within bands. Dunbar et.al. describe feldspathic spherulites as developing under high-temperature diffusion controlled crystallisation during the cooling phase of a rhyolite.

‘*Slower cooling (rhyolites) can form microscopic crystals in the lava (which) results in textures such as flow foliations, spherulitic, nodular, and lithophysical structures. Some rhyolite is highly vesicular pumice. Many eruptions of rhyolite are highly explosive and the deposits may consist of fallout tephra/tuff or of ignimbrites.’* Ex. Wikipedia.

The Bouley Bay rhyolites represent one of a series of episodes of volcanic activity which took place about 533Ma and were later subjected to folding during the Cadomian Orogeny. At Archirondell another sequence of flow-banded rhyolites occur but these show columnar jointing (Fig. 13).

The rhyolites showed cm banding of light and dark bands, sometimes showing flow structures similar to small scale recumbent folds and elsewhere columnar jointed. This outcrop caused a great deal of discussion – not only the origin of the dark bands, which are very common in these rhyolites but also the formation of the columnar jointing which is more commonly associated with basic magmas. David explored the origins and formation of both.

First, the dark bands: they are possibly obsidian which is a black volcanic glass produced on the surface of the lava flow due to rapid cooling or chilling, or are a mineral such as hornblende. Second, columnar jointing - normally hexagonal in cross section, is produced when the interior of the lava flow cools much more slowly than the edges. Classic examples are Giants Causeway, N. Ireland and Fingall’s Cave, Island of Staffa, both of which are in basalts.

Fig. 12: Spherulites in banded rhyolites. Bouley Bay

Fig. 13: Columnar jointed banded rhyolite, Archirondel

Basalts are extruded in fast moving low viscosity flows of 1200ºC, which can travel many km and accumulate in great thicknesses while still molten. They frequently exhibit columnar jointing due to shrinkage during cooling. However, rhyolites, unlike basalts, are highly viscous, slow moving lava flows, which are usually extruded at 500ºC and found in or close to the volcanic vent. Further, pyroclastic flows, which are very acidic, can transport fragmented rhyolitic lava great distances and speed as occurred at Mt St Helens. Ignimbrites (welded tuffs) are the product of pyroclastic flows and can exhibit banding due to a combination of layers of collapsed bubbles of lava and ash together with stratification as the different components are precipitated from the air born flow. Millward & Lawrence note that the Stockdale Rhyolite extends for 13 km (Kentmere to Shap) in the Lake District. It comprises ~185m of pink to pale grey, massive to intensely fractured, platy-jointed, flow-banded and flow-folded rocks of rhyolitic composition, locally underlain and overlain by impersistent beds of clastic rocks composed largely of pumice and felsic fragments and suggest it is a rheomorphic ignimbrite due to its length to thickness ratio, textural characteristics and associated sedimentary rocks.

Possible methods of occurrence therefore are shown below, but all three options have aspects that are difficult to reconcile and no firm decision was made:

1. The rhyolites' obsidian bands suggest that if produced by chilling, caused by contact with the air then the flows were very thin. To achieve the situation where the slowly extruded rhyolites, can form a molten mass, able to cool and create columnar jointing, then the flows must have erupted virtually continuously. BUT - Viscous lavas by definition are unlikely to be erupted in thin layers as they would solidify almost immediately.
2. The rhyolites are not lava flows but pyroclastic flows the banding being a product of heavier particles separating out by preferential deposition from the ash cloud. The flows would need to be continuous and to still be molten on deposition to form a molten mass, so that columnar jointing would occur on cooling. BUT - A series of pyroclastic flows would probably not produce a molten mass sufficiently thick to cool and produce columnar joints.
3. The bands are not obsidian but a mineral that has settled out in layers as a result of preferential crystallization and gravity separation. Hornblende seems the most likely. The extrusion of the lava was slow enough to maintain the integrity of the mineral banding. The lava flow was thick enough to achieve columnar jointing on cooling. BUT - Producing mineral separation and gravity settling in a viscous magma seems difficult as does maintaining the integrity of the bands on extrusion but the flow structures do contain them.

One outcrop at Archirondel Beach showed an interesting sequence from an agglomerate into a volcanic lava flow, at the base of which were 'clasts' from the underlying agglomerate. This basal section of the flow passed up into 'clast-free' rhyolite. The agglomerate may have been blasted just before the lava flow erupted; lying on an irregular surface over which the lava flowed, the cobble-sized agglomerate clasts were picked up and engulfed within the flow, were cooked and deformed slightly.

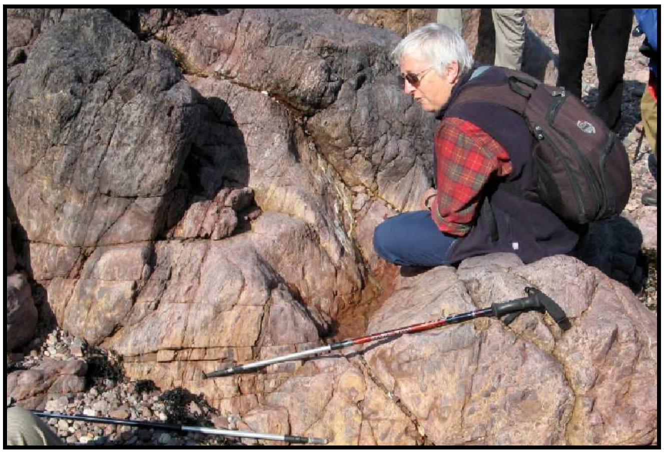

Fig. 14: Janet is on clasts in base of flow passing up into banded rhyolite.

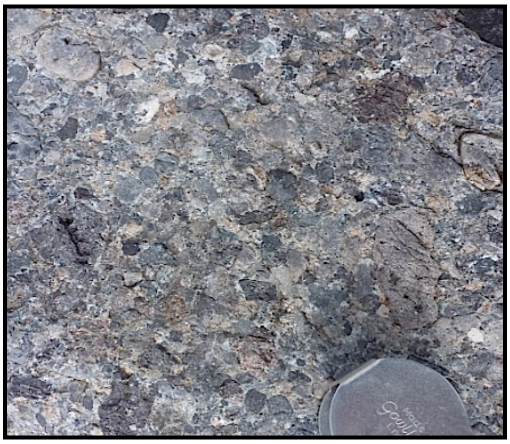

Fig. 15: Agglomerates from Bouley Bay sequences

**Volcanic Sediments - Agglomerates of Giffard and Bouley Bay**

The agglomerates were composed of broken lava fragments (larger than 20 mm in diameter) in a fine matrix, formed by explosive volcanic eruption. Fig. 15 examples are from Giffard Bay and Bouley Bay.

NOTE: Auckland University describe granite (and granodiorite) as being *'produced in volcanic arcs, and in mountain building, resulting from the collision of two continental masses. The earliest continental masses were products of the accumulation of volcanic arcs, which is why granite lies in the cores of all continents.'* This supports the igneous plutons and volcanic rocks of Jersey together forming part of in the Cadomian Island Arc Complex.

## 5. Sedimentary Sequences of Jersey

The dominant sediments are the Jersey Shale Formation and the Rozel Conglomerate Formation

### Jersey Shale Formation

Le Pulec is in the NW of Jersey, at the N tip of the Jersey Shale outcrop. The Formation is thought to correlate with the Upper Brioverian metasediments in Normandy and to have an age of approximately 680-570Ma (Upper Brioverian). The name is actually a misnomer as the formation consists of sandstone, siltstone and mudstone turbidites. Deposition is thought to have occurred in a submarine fan environment on a continental basement close to a subduction zone (similar to Indonesia today). Our leader, Ralph Nichols, explained that the sediments we were about to examine were characteristic of foreset to bottomset beds of fan fringe deposits.

On the foreshore, at the N end of St. Ouen's Bay, we saw bedded grey siltstones and grey pinkish/purplish fine sandstones varying in thickness from several cm to ca.30 cm which were dipping at an estimated 25º-30º NE. The thinner beds of finer material represented deposition due to smaller earthquakes whereas thicker beds of coarser material were due to more powerful events which produced turbidity currents having the power to drive further into the fan (Fig.16).

Fig. 16: Sequence of Jersey Shale turbidites

Fig. 17: Graded sequences in turbidite beds.

We saw many varied and interesting structures within these beds including: cross bedded turbidite sequences fining upwards and grading from coarser material to finer (Fig. 17). Fine examples of miniature cross bedding in the paler coarser material (Fig. 18) grading up into finer, darker, siltier sediments, with cut and fill structures, flow ripples (Fig. 19) and load casts sometimes present. Finally we examined an example of sole markings in an outcrop by the roadside (Fig. 19) before stopping for lunch.

Fig. 18: small scale cross beds in well graded flow, cut and fill structure beneath pencil.

Fig. 19: (R) Load casts on base of flow.

Fig. 20: Disturbed sediments and syn-sedimentary faulting in Jersey Shale turbidites.

The Jersey Shale Formation has undergone low-grade regional metamorphism due to the Cadomian orogeny (between approximately 675-480 Ma). Only at Le Pulec are metamorphic minerals visible (cordierite in hornfels) in the metamorphic aureole adjacent to the NW Granite.

## Rozel Conglomerate

The Rozel Conglomerate occupies the NE corner of Jersey. The Conglomerate is thought to be late Cambrian to Ordovician in age and was laid down after the Jersey volcanics. It represents a flood plain type environment with periodic flash floods bringing sediment down from the hills or mountains formed by uplift during the Cadomian Orogeny.

The base of the Rozel Conglomerate is unconformable on the eroded surface of the rhyolites of the Jersey volcanics with a base consisting of sandstones, grits and mudstones termed the 'red beds'. We did not visit an exposure of the unconformity itself but our first location was still in the 'red beds' section although higher in the sequence.

### Location 1 – La Solitude Farm

The exposure was at the side of a lane and ranged from ca. 3-5m high. The conglomerate consisted of coarse units of highly unsorted sub-rounded to rounded pebbles ranging from approximately 0.5cm to 20cm in a yellowish clay type matrix. Within the exposure was a bed about 60cm thick consisting of pinkish fine mudstone material for approximately 15cm underlain by more silty purplish material (Fig. 21). No sedimentary structures could be seen in this layer but we were able to make out cross bedding and wedging out structures (Figs. 22, 24) and small-scale cross bedding (Fig. 23) in the yellow coarser units.

We discussed an interpretation that the oxidation exhibited by the purple/pink layers indicated on-land deposition. The particles were held in suspension in a relatively high-energy environment where the energy then dropped suddenly prior to deposition; such conditions would not allow the formation of ripple structures. The coarser units represent a sudden influx such as in a flash flood. The degree of rounding of the pebbles and the presence of the finer mudstone/siltstone layers indicated that deposition took place relatively far from the original source of the material.


Fig. 21: Pink mudstones underlain by purplish siltstones.

Fig. 22: Wedging out structures with faint cross beds.

Fig. 23: Well defined cross beds in yellowish sandstone unit.

Fig. 24: Erosional base to a sedimentary wedge with some cross bedding, cuts into underlying beds of sandstone.


Fig. 25: Clast of lamprophyre in the Rozel Conglomerate, St Catherine's Bay

Fig. 26: Clast of rhyolite in the Rozel Conglomerate, St Catherine's Bay

Walking further along the lane, we noticed a tree root that had grown along the line of what appeared to be a normal fault which had displaced the mudstone/siltstone layer by about 30cm.

**Location 2 – St Catherine's Bay**

Our next stop was beside La Grande Maison slipway in St Catherine's Bay. This outcrop was above the 'red beds' in the succession. The conglomerate was again poorly sorted with the majority of clasts being sub angular to sub rounded and ranging between 2cm to 30cm. Jointing was also present. The clasts included examples which may have been Jersey Shale, lamprophyre (Fig. 25) and igneous rocks such as rhyolites (Fig. 26) and possibly a few granites (Fig. 27).

Fig. 27: Granite clasts in Rozel Conglomerate, St. Catherine's Bay.

Fig. 28: Erosional bases to conglom's and large scale cross bedding.


Fig. 29: Rozel Conglomerate at Rozel Bay, showing good bedding features.

We then moved along the foreshore to an outcrop near the lifeboat station. Here the beds were dipping approximately NNE and showed examples of erosive surfaces and coarse cross bedding (Fig. 28). The mudstone /siltstone layers were not present at this location and we discussed how, together with the more sub angular nature of the clasts, this might represent an environment closer to the original source of the sediment. The fact that we saw few granite clasts in the conglomerate at the St Catherine's Bay location might be interpreted as indicating that the erosion processes leading to this conglomerate had not yet exposed significant granite.

**Location 3 – Rozel Bay**

The outcrop here on the foreshore exhibited an anticline structure. The anticline, the result of tectonic activity after the conglomerate had been deposited, had a N-S orientation rather than the expected E-W orientation. This anticline may have resulted from a shear/wrench fault.

The clasts in the conglomerate appeared less angular, more well rounded and better sorted than at La Maison Slipway with fewer rock types and a greater proportion of material that might have been from the Jersey Shale. The clasts were altogether more uniform in size, composition and colour than at St Catherine's Bay all suggesting that the source of this outcrop was different from the former outcrop. It was surmised this bed was also younger. However moving towards the current top of the anticline the clasts had become more angular but still uniform in colour and composition. Large-scale cross bedding was again evident in areas at this location (Fig. 29).

## 6. Quaternary Sediments, Archaeology and Building Stones

Over the last half million years of the Pleistocene, Jersey was part of the European landmass. Four changes in relative sea levels can be traced by wave-cut notches and raised beaches: at 8, 18, 30 and 35m above mean sea level. The lowest, dated to 121Ka, the Ipswichian Interglacial, is the easiest to identify. We saw examples at Archirondel, St Catherine's, Rozel and Giffard Bays. At La Pulec, a rock fissure, illustrated below, showed a clear sequence of three deposits: sand and gravel of a beach, overlain by angular shale in head emplaced in wet conditions, above which was laid unsorted shale from a dry environment (Fig. 30).

Other Pleistocene deposits seen included head and unsorted rock remnants brought down in cold conditions, and loess and well-sorted silt, windblown in dry glacial conditions. Often both were found together and hard to distinguish. There was also Holocene peat, alluvium and blown sands. At Green Island, the base rock was overlain by gravel with a thick loess deposit above; later covered by blown sand. During low tide at La Rocque we were shown examples of a silty clay sequence in hollows in the bedrock, thought to be Pleistocene loess reworked in the Holocene (Nichols, 2013 unpublished.)

Over the last 250,000 years, during warmer periods of the Pleistocene, people have been present on Jersey, although it was then a rocky promontory of Europe. As the ice retreated, sea levels rose and hunting lands were lost. Hunter/gathering was replaced by Neolithic (Neo) farming, and Jersey had become an island.

Fig. 30: Rock fissure at Le Pulec, see text.

Fig. 31: La Pouquelaye de Faldouet

Between us we visited three early Neo passage graves (4000-3200BC), monuments typical of the Atlantic coast of Iberia: La Hougue Bie, the largest on the Island is 50m diameter and 12m high, the damaged Dolmen de Mont Ube' and La Pouquelaye de Faldouet, shown in Fig. 31.

These were built of earth-set slabs of stone, their long edges vertical (orthostats) upon which capstones were set, some with only three point contact, assembled like the 'house of cards' made by children. The passages to the internal chambers were carefully positioned. Two were aligned to the equinoctial sunrises so that their chambers would then have been illuminated. The buildings were sealed, covered with earth and rubble mounds and the surrounds of the entrances corbelled. Although human remains and grave goods were found, they were few and it is thought these complex buildings were probably used more for ritual and sacred rites than burials. La Hougue went from use from ~ 1500BC.

The gallery grave at Ville-es-Nouax (3250-2850BC) late Neo or Copper Age was a later type, characteristic of Brittany and the Paris Basin, also built of orthostats and capstones and covered by a mound – but rectangular. Two separate levels were found inside; one had few finds but the upper contained 16 Early Bronze Age (EBA) Bell Beakers and Jersey Bowls in a small cist. Near this grave were two cists, a cairn and a 'cist-in-circle' (2250BC). This cist with a kerb surround was once covered by a mound, but empty except for some ashes. Nearby was LBA urn cemetery (800BC) demonstrating a remarkable continuity of use.

It remains unsolved how this apparently small population of farmers obtained and moved these heavy stones and built so many of these monuments on this small island. These 6000 year old buildings are the oldest in Jersey. They are made of local granites, speckled diorites and some banded rhyolites, but selected stones from more distant sources were also used.

### Building Stones

We saw examples of granite, granodiorite, diorite, rhyolite, andesite, agglomerate, Jersey Shale, greywacke and siltstone used to build farms and houses, walls and sea defences, most local to the source of their stone. At one time both on land and offshore there were about 40 Jersey quarries supplying stone for local building and for export. The builders of castles, forts and later public, commercial and industrial buildings favoured local granites. In the S, much granite and granodiorite was quarried from Les Minquiers, part of the SE Igneous Complex. Mont Orgueil Castle at Gorey (Fig. 32) is a good example. The SW and NW used the granite quarries at La Corbiere and the N coast, with Rozel conglomerate used in the NE. Stone does not travel easily, and while building in local stone continued, more convenient quarries, some with easy access to the sea were also chosen and where special colours, textures, natural shapes or aesthetic balance demanded, other sources were sought.

Until the 19C many roofs were of thatch, but then Dutch pantiles, Welsh or Normandy slate was used. We thought that the majority of houses had slate roofs. Although granite-faced buildings are the majority, a few buildings are of brick, and there is a brick-works at St Saviours. Loess was used for bricks but this is no longer permitted. Sand was dug from the beaches, but on Jersey these belong to the British Crown, and removal of sand, shingle and rock is now prohibited; sand and gravel now come from pits behind St Ouen's Bay.

Fig. 32: Gorey Castle made of local granite.

Fig. 33: La Hougue Bie. One of the finest Neolithic passage graves in Europe

The island has no limestone, and early mortar was made by boiling shells in seawater to make slurry that was poured between the wall faces, or by heating shells to produce quicklime. Since medieval times lime has been imported.

Jersey's stone quarries were a valuable and significant industry, but were unsustainable. There are only three now working. Some decorative stone is still produced and building stone recycled, but aggregate and road metal are the main output. The island has a large population: 97,850 in 2011 (a density of 819/km$_2$ whereas Surrey is 683). Very strict rules are applied to potential residents and this is perhaps the reason that the 19-20C housing boom seems to have ended. Jersey is a wealthy island, and most building material is (like everything else) now imported. Many new buildings such as the newly refurbished airport are now steel, concrete and glass.

Finally, a big thank you to Graham Williams for organizing the trip to Jersey which so many people went on. Also our thanks to Ralph Nichols for dedicating a week of his time to leading the group all round Jersey and introducing us to the complexities of its geology – such a small island with so much varied and interesting geology to offer. And lastly, to introduce you, the newsletter reader, to his website: *Jersey Geology Trail* - http://www.jerseygeologytrail.net/.