Chapter 11

The Middle Lava Formation: The construction of lava shields

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Following the development of the rivers, lakes and swamps which resulted in the deposition of the sedimentary units of the Coal Formation and the pyroclastic eruptions preserved as tuffs within the Volcaniclastic Sandstone Formation, effusive volcanism re-started and much of the Faroes area was covered with compound pahoehoe lava flows of the Middle Lava Formation (MLF). These lavas were distributed by complex intra-flow tube systems and were erupted onto a land surface similar to the present-day island of Hawai'i. Broad lava shields formed on an initially relatively flat land surface, with occasional hiatuses marked by the formation of distinctive red soils. The top of the Middle Lava Formation is typically marked by a thick sedimentary deposit, usually a conglomerate, although in places it is not present and the upper boundary of the Formation is taken as where sheet lava flows of the Upper Lava Formation become dominant.

Distribution

The Middle Lava Formation (MLF) is up to 1400m thick, for example in the area around Vestmanna on Streymoy (Rasmussen & Noe-Nygaard 1970b; Waagstein 1988). It is preserved on all of the islands except Mykines, where it may have been removed by late Tertiary erosion, and on Nolsoy, Svinoy and Fugloy, where it most likely is present below the Upper Lava Formation strata that form these islands. In simple terms, the MLF gives way towards the south and west to outcrops of the Lower Lava Formation, whereas towards the north and east it is capped by flows of the Upper Lava Formation (Figure 11.1). Spectacular exposures of MLF flows form many of the cliffs of Suðuroy, Lítla Dímun, Stóra Dímun, Skúvoy, Sandoy, Vagar, Streymoy, Eysturoy, Kalsoy, Kunoy, Bordoy and Viðoy, often best appreciated when viewed from offshore. Individual sections in excess of 300m thick are common and an example is illustrated in Figure 11.2.

Lava Characteristics

Figure 11.3 illustrates the main features of **compound pahoehoe flows**, a Hawaiian name used to describe lavas with smooth, commonly ropy or crenulated, surfaces, caused by their viscous flow during eruption (Cas & Wright 1987). Virtually all of these features are found within the MLF flows of the Faroe Islands, for example at the spectacular exposures at Viðareiði on the west coast of Viðoy, aspects of which will be described later in this chapter. Another important and well-developed feature of these pahoehoe lavas is the presence of **tube systems** that acted as feeders to the advancing **flow fronts**. Figure 11.4 illustrates the relationships between such tubes and the flow fronts, with the possibility that we can determine the direction of flow based upon certain features that, potentially, may be preserved.

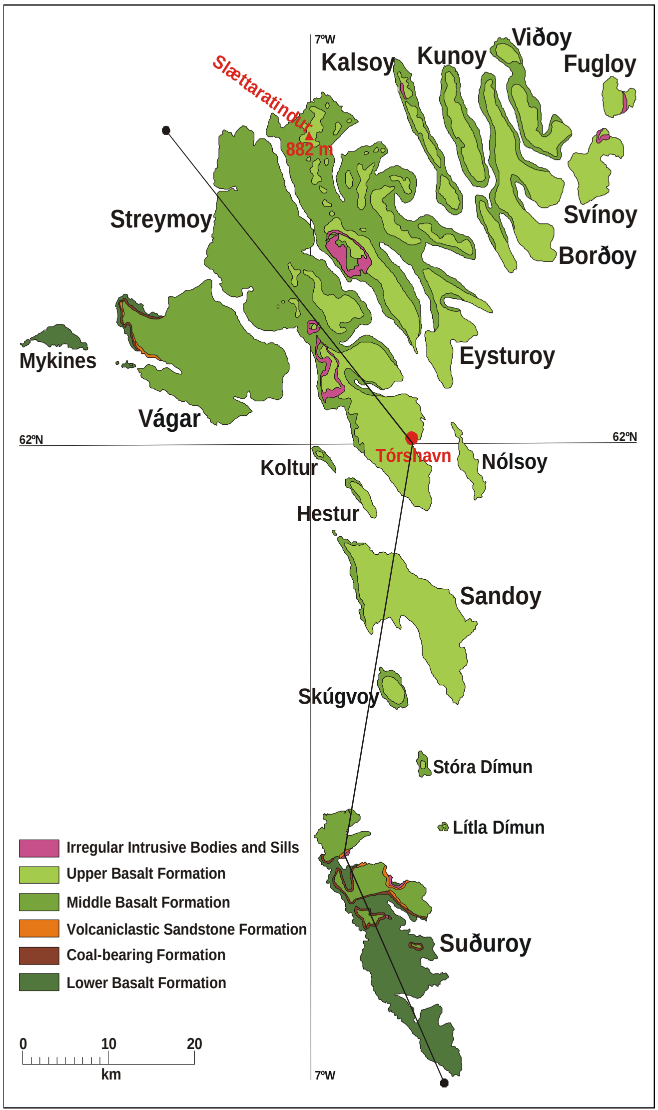

Figure 11.1. Geological map illustrating the distribution of the Middle Lava Formation.

Flow Thicknesses

Individual MLF flows are up to 20m thick, each comprising thinner flow units that range from a few tens of centimetres up to 2m (Figure 11.2). For example, within the Vestmanna-1 drill hole on Streymoy (Figure 11.1), the **flow units** range from a few centimetres up to 14m, with an estimated average of around 1.8m (Waagstein & Hald 1984). Comparable thicknesses are recorded from other ancient volcanic sequences, for example the Miocene Snake River Plain flows of Idaho, USA, and the Paleogene lavas of the Inner Hebrides, Scotland. By way of contrast, the pahoehoe flows erupted in recent times on Hawai'i are considerably thinner. Towards the top of the MLF, the flow units tend to be thickest, reaching a maximum of approximately 10m, indicative of elevated rates of magma eruption.

Morphology

The compound MLF flows appear to have flooded out over (at least initially) a very flat land surface, perhaps with slope angles of less than 1 degree (Noe-Nygaard 1968). Consequently, Noe-Nygaard (1968) determined that these near-horizontal sequences had developed into broad **lava shields** of a variety referred to as the **scutulum type**, with diameters of up to 15km. It is difficult to trace flow units for any significant distance, even where they are perfectly exposed on sea cliffs, mainly because of their ribbon-shaped geometries, with each succeeding flow tending to fill in the low ground created by the previous lava, or earlier flow units of the same eruption, as illustrated in Figure 11.2. Based upon our knowledge of the eruption characteristics of such lavas, it is likely that they flowed several kilometres away from their **vents**, although such features are notoriously difficult to identify and have not been recognised with any confidence for the MLF.

Surface features

The commonest surface features observed throughout the MLF sequence are **ropy structures** or surface wrinkles, of the types illustrated in Figure 11.5. At Viðareiði on Viðoy, lava ropes are observed on both the upper and lower surfaces of individual flow units. Large-scale ropes cover areas up to 3m by 2m, and their curved shapes act as useful flow-direction indicators. Smaller-scale ropy surfaces are observed on the upper surfaces of **lava tongues**, with a few centimetres of relief and the appearance of twisted bread sticks, thus producing a braided pattern on the lava surface.

Figure 11.2. A typical exposure of compound flows with lava tubes within the Middle Lava Formation, Togara, west Eysturoy.

Only in cases when the top surfaces of lavas are covered by younger flows relatively rapidly and there is insufficient time for any substantial **weathering**, will such delicate features be preserved. Otherwise, degradation of the ropy surfaces will occur, with the development of oxidised and reddened lava, possibly weathering further to produce a **palaeosol** (i.e. a fossil soil), indicative of reaction with the atmosphere. One advantage of the development of weathered flow tops is that it allows us to determine the thicknesses of individual compound flows and to say something about the length of time between successive eruptions. For MLF flows, this appears to be relatively variable, in some cases flow tops are perfectly preserved, indicating short hiatuses between eruptions, whereas in other examples substantial soils have formed over relatively long periods, perhaps several tens of thousands of years. We will return to this topic later in the chapter.

Internal features: lava tubes

The internal features of MLF compound flows are typically best observed on coastal outcrops, where more continuous exposures are common. Of particular note are certain spectacular infilled **lava tubes**, ranging from large **master tubes** to smaller **distributary tubes** (Rowland & Walker 1990), as illustrated in Figure 11.4. The master tubes form prominent, stand-alone features, typically more resistant to weathering relative to the surrounding flow units, and commonly with some form of radial **cooling joints**. Of the relatively few recognised, although it is suspected that many more are present, the largest forms an approximately 100m long spit of land extending seawards on the north-west coast of Sandoy, at Hvalsryggur (Figure 11.6). The tube is 10-20m wide, giving it a cross-sectional area of approximately 160m^2, and hence a minimum volume of 16000m^3. The same tube-like profile is noted on Trøllhøvdi Island to the north-west, thus extending the tube length by at least 140m, without any substantial change in size. Other lava tubes that have resisted erosion are seen on the coastal section at Rituvík, Eysturoy (Figure 11.7) and along the coastline at Sundsmunnin, approximately 800m south of Viðareiði on Viðoy. An excellent example of a master lava tube encased within MLF flows occurs along the coastline at Froðbiarbotnur, some 3km north-east of Tvøroyri on Suðuroy. This tube is approximately 5m high and 9m wide, giving it a cross-sectional area of some 35m^2. It is particularly obvious as it stands in contrast with the paler host lavas, with clear **apophyses** extending out from the top of the tube.

An example of distributary lava tubes, akin to those described by Rowland & Walker (1990) (Figure 11.4) occurs within the MLF sequence at Viðareiði on Viðoy (Figure 11.8). They occur within pahoehoe flow units and their lobate shapes are akin to **pillowed lavas**. Indeed, such flows may be regarded as the terrestrial equivalent of subaqueous pillow lavas, advancing by inflation of the flow by magma fed along the complex tube systems.

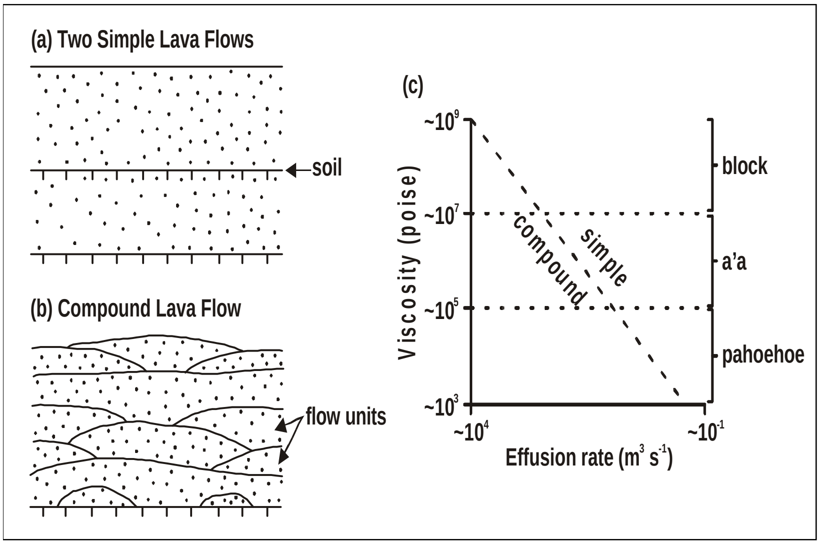

Figure 11.3. The two main types of terrestrial lava flow: (a) Two simple lava flows with an intervening soil; (b) A compound flow of the type forming the Middle Lava Formation; and, (c) The postulated relationship between simple and compound lava flows, illustrating the effects of magma viscosity and effusion rate. (a) & (b) after Cas & Wright (1987); (c) after Walker (1970).

Cooling rates and amygdale development

Two types of pahoehoe flow unit were recognised by Walker (1987), **P-type** (pipe-bearing) and **S-type** (spongy), and both are present within the MLF. The P-type is dominant and each example can be separated into a number of zones, based upon the distribution of **amygdales**, typically calcite and/or zeolites, which represent gas cavities filled by minerals precipitated from **hydrothermal waters** that flowed though the lava pile during burial. Figure 11.9 shows a typical P-type flow unit from Viðareiði on Viðoy, which can be separated into three zones. The flow unit is approximately 1.6m thick and comprises a basal crust, a lava core, and an upper crust. The 10cm-thick basal crust is characterised by pipe amygdales that achieve lengths up to 8cm, although never in contact with the base of the flow. Curvature of the pipes can be used to infer the flow direc-

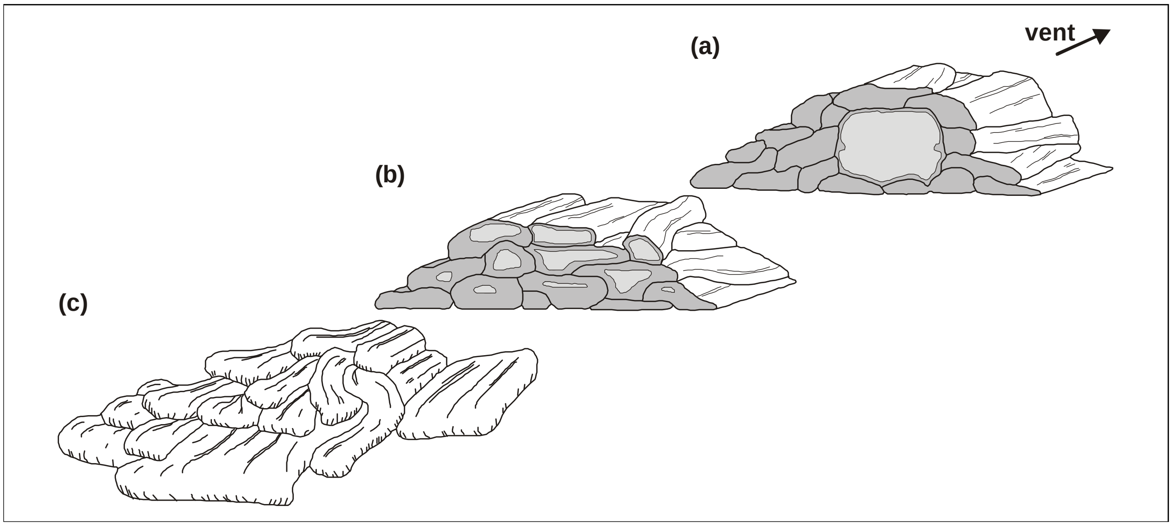

Figure 11.4. Tube system in a pahoehoe lava flow. Master tubes, (a), form by the coalesence of several adjacent smaller tubes or by roofing over of open channels. Master tubes deliver lava to the distal parts of flows, where there is a system of small distributary tubes, (b). At the flow front, the lava emerges in several small single flow unit tubes, (c), which have cross-sectional areas of up to 1m². After Rowland & Walker (1970).

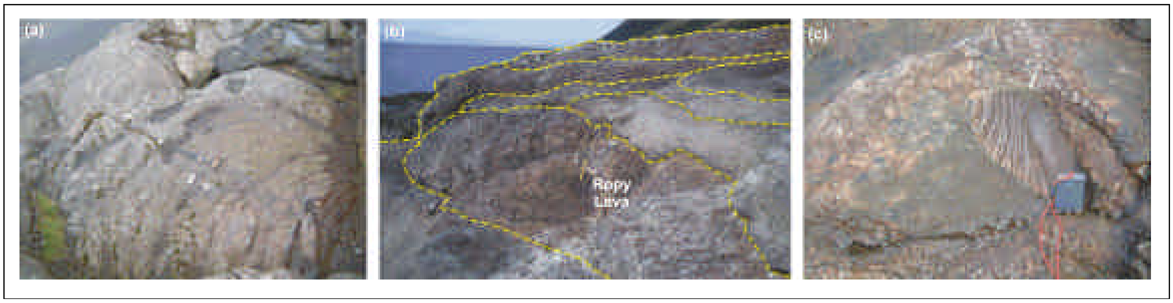

Figure 11.5. Views of ropy lava surfaces from the Viðareiði lava, Viðoy. (a) Large-scale, convex ropes covering an area of approximately 3m x 2m. The shape of the ropes tentatively suggest flow towards WNW. The hammer is approximately 40cm long and its shaft is aligned parallel to the flow direction. (b) Flow units within the Viðareiði lava, with an area of ropy texture indicated. (c) Detail of area highlighted in (b). The ropes have the appearance of twisted bread sticks and have a relief of up to 3cm. The compass is approximately 10cm x 6cm.

Figure 11.6. Views of the lava tube forming Hvalsryggur spit, NW Sandoy. The lava tube is approximately 100m long by 10-20m wide. The tube outline is also observed on Trøllhøvdi Island, to the NW, extending the tube by at least 140m.

Figure 11.7. Lava tube at Rituvík, Eysturoy. The tube forms a 15-20m long sinuous elliptical cylinder, approximately 1.1m high by 3.2m wide, giving it a cross-sectional area of 2.8m^2.

tion, albeit possibly only local. The upper crust is, on average, 25cm thick and is dominated by elliptical amygdales, up to 2cm across. Between the lower and upper crusts is a central featureless, or massive, zone with irregular joints and fractures, devoid of amygdales. Another excellent example occurs on the south side of Stórafjall, on the east side of Skálafjørður in south-east Streymoy. Hald & Waagstein (1988) reported similar features within the lavas cored in the Vestmanna-1 drill hole, and with similar dimensions.

Figure 11.8. Distributary lava tube of the Viðareiði lava, Viðoy. The tube has an approximate area of 0.15m^2.

This distribution pattern of amygdale shapes, characteristic of P-type flows, has been described from recent **inflated pahoehoe lavas** on Hawai'i (Hon et al. 1994) and in the Miocene lavas of the Columbia River Basalt Group (Self et al. 1996; Self et al. 1997). According to Hon et al. (1994), the boundary between the central zone and the upper crust marks the end of the injection of fresh lava into the lobe, and when the lobe interior became stagnant. Furthermore, an estimate of the time interval during which the lobe was fed by lava can be obtained by determining the time required to form the upper crust. For Hawaiian lavas, the time taken can be estimated from the empirical equation:

$$t = 164.8\, C^2$$

where: t is the time in hours, C is the upper crust thickness (in metres), and 164.8 is an empirically-determined constant (Hon et al. 1994). Time differences (i.e. cooling rates) between the Faroese lavas and Hawaiian lavas may be anticipated due to any differences in rainfall (hence affecting the cooling rate) and thermal properties of the lava (heat capacity, diffusivity, latent heat of crystallisation). Reasonably assuming that the above equation can be applied to the MLF flows, then the example at Viðareiði would have flowed for approximately ten hours, and the average flow unit in the Vestmanna-1 sequence would have been active for just over a week.

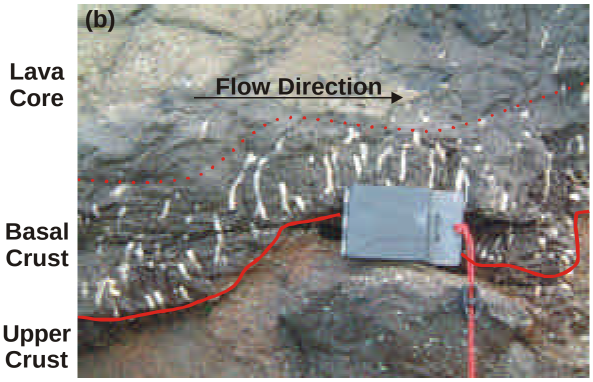

Figure 11.9 A P-type pahoehoe flow unit within Viðareiði lava, Viðoy. (a). The flow unit is approximately 1.6 thick and can be subdivided into three zones: a basal crust, the lava core, and an upper crust. . The basal crust is 10cm thick and is characterised by near-vertical pipe amygdales. The lava core is compact and massive (i.e. nearly featureless), with irregular jointing. The upper crust is 25cm thick and is dominated by oval amygdales, each with a maximum diameter of 2cm. The hammer is approximately 40cm long. (b) Detail of the basal crust. The pipe amygdales are up to 8cm long, some curved in the interpreted direction of flow. The presence of pipe amygdales suggests that the flow was erupted onto a near-horizontal land surface.