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A LABORATORY SIMULATION OF BASALTIC LAVA FLOWS

MARK A. HALLWORTH, HERBERT E. HUPPERT
Department of Applied Mathematics and Theoretical Physics,
University of Cambridge, Silver Street, Cambridge CB3 9EW, UK
and
R. STEPHEN J. SPARKS
Department of Earth Sciences, Downing Site,
University of Cambridge, Cambridge CB2 3EQ, UK

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The morphology of basaltic lava flows was investigated by allowing molten wax to flow down a slope and solidify. Observations were made of the distribution of flows erupted at different times, and on the formation of tubes. It was found that the rate of effusion played the most important role in determining the final flow morphology. High effusion rates producted straight, open channels with shallow cross-sectional profiles and simple distribution patterns. Slow effusion rates yielded compound flow units with much thicker cross-sectional profiles and were predominantly fed by meandering, branched tube systems. Distribution of the material erupted at different times for slow rates of effusion, was complicated and random. Tube formation occurred by the progressive advance of inflated, lobate toes of molten fluid and also by roofing over of open channels.
KEY WORDS: Basaltic lava flows, effusion rate, flow morphology, tube formation.

INTRODUCTION

The flow and emplacement of basaltic lava are complex phenomena and result in a wide variety of complex morphologies. Field observations, experimental simulations and theoretical studies indicate that a great many factors influence the development of lava flow fields, including effusion rate, vent geometry, slope, topography, lava rheology, degassing and crystallisation. A comprehensive quantitative model for the flow of lava has not yet been developed. However, laboratory experiments using other kinds of fluid as an analogue of lava have provided useful insights into lava behaviour (Hulme, 1974, Greeley and Womer, 1981). This paper describes an experimental system for simulating basaltic lava flows using molten polyethylene glycol waxes under water. This system avoids some of the problems encountered with surface tension effects in experiments using molten wax in air, and enables the influence of cooling and solidification on the flow morphology to be studied. The experiments are also valuable for investigating how magma discharged at different times during the course of an eruption is distributed within a lava flow. If lava changes in composition with time, as it does for example, when erupted from a zoned magma chamber, it is important to determine the spatial and temporal relationships of chemically different units preserved within the solidified lava field.

OUTLINE OF EXPERIMENTS

The large number of controlling independent variables associated with lava eruptions makes experimental modelling difficult. Analyses of lava flows by Walker

(1973) and Hulme (1974) suggest the following factors to be of importance:

i) effusion rate;
ii) viscosity (and independently temperature, composition and gas content);
iii) yield strength (determined by crystal content, size and shape);
iv) slope angle; and
v) pre-existing topography.

Our experimental study was designed to see what conclusions could be drawn on lava flow morphology and distribution by the controlled variation of effusion rate, temperature, and the angle of inclination of the slope down which the flow moved.

The modelling medium was molten Polyethylene Glycol (PEG) 1000, which is a water soluble wax with a melting range of 37–40°C. PEG waxes have been used successfully to simulate lava flows by Greeley and Womer (1981), who cite an evaluation of such waxes for this purpose by Hogdson (1969). The rheological properties of PEG waves are well defined (Union Carbide, 1978); the effective kinematic viscosity of molten PEG 1000 varies as a function of temperature from 0.69 $cm^2\ s^{-1}$ at 50°C to 0.27 $cm^2\ s^{-1}$ at 80°C. An important departure from previous studies is that our flow simulations were performed on a slope submerged in water at room temperature. Experimentation under water eliminated the large, and in this context irrelevant, surface tension effects that would occur in air, and also permitted a more efficient heat transfer between the molten wax and its environment. The laminar nature of the flows ensured negligible mixing with water and dilution of the PEG wax, and the time scale of the experiments was much shorter than that required for the soluble destruction of all but the thinnest of solidified structures. (Experiments never ran for more than 25 minutes, whereas major solidified structures could be preserved without dissolution under still water for several hours.) Most experiments were recorded by colour photographs and video sequences. We also produced a 16 mm movie film, which depicts the major morphological variations as indicated in Table 1.

It is important to note that the experiments are qualitative and preliminary. They exhibit features which can be identified with those observed in real basaltic lava flows. Since the dynamical equations governing the flow, cooling and solidification of lava are not adequately known, a fully quantitative comparison incorporating detailed scaling arguments is not possible at this time.

APPARATUS

The experimental apparatus is shown in Figure 1. The assembly was designed to deliver a constant flow of molten wax at a set temperature to the top of a sloping plane. The wax was contained in a one-litre glass bottle (the "magma chamber") and linked to the top of the slope by a thin glass feeder tube (the "vent") incorporating a valve to control the rate of effusion. The internal diameter of the feeder tube was 0.7 cm. To prevent solidification of the wax prior to delivery and to maintain a constant temperature, the bottle, feeder tube and valve were all enclosed in a lagged water jacket, which was circulated and heated by means of a thermoboy. A thermistor positioned in the mouth of the tube at the base of the bottle enabled us to monitor the output temperature, which never varied by more than ±0.5°C from the pre-determined value. Wax release onto the slope was gravity fed, with a flow rate

Table 1

Run	Effusion rate Q(cm^3 s^{-1})	Initial temp (°C)	Slope angle (°)	Cross-sectional aspect ratio (height/width)	Description
[a]A	0.42	50	15	High	Compound flow with tube system
[a]B	6.0	50	15	Low	Straight, open channel
[a]C	2.14	50	15	Intermediate	Meandering channel, temporary roofing
[a]D	1.27	50	15	Intermediate	Meandering channel, temporary roofing
E	0.56	50	15	High	Compound flow with tube system
F	1.68	50	15	Intermediate	Meandering channel, temporary roofing
G	1.56	40	15	High	Slightly meandering single tube
H	0.94	60	15	Low	Straight, open channel
I	0.38	60	15	High	Compound flow with tubes and side break-outs
J	0.62	50	30	Low	Straight, open channel with blocky, mobile crust

[a] Repeated for the production of a 16 mm movie film.

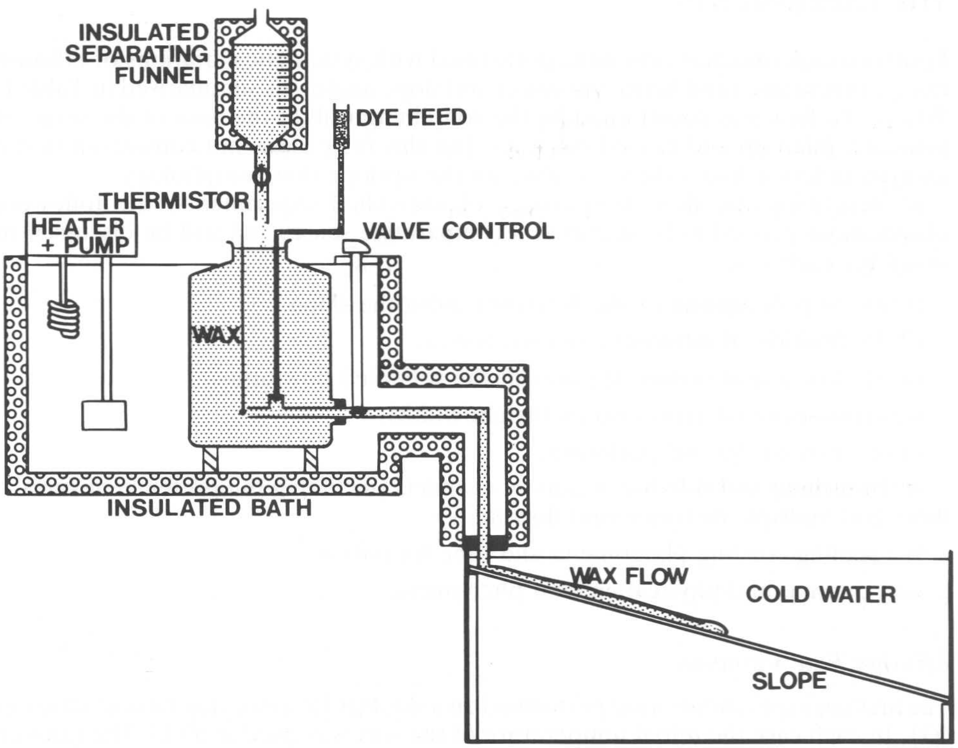

Figure 1 Schematic diagram of experimental apparatus.

dependent on the hydrostatic head in the bottle. To keep this constant for any given valve position, a second source of molten wax was placed in a lagged, graduated separating funnel above the neck of the bottle. The fluid level in the bottle was continually topped up to a pre-determined mark in the neck by hand-controlled introduction of wax from the separating funnel. Values of effusion rates were known approximately from calibrated valve positions, but were calculated more exactly from the volume of wax added to the botle to maintain a constant head and the timed period of flow.

To aid flow visualisation and subsequent analysis of distribution patterns within the solidified flow unit, the wax was stained different colours throughout the course of each experimental run. This was achieved by drip-fed introduction of dyed liquid PEG 400 into the feeder tube. (A PEG 400/dye mix was used to reduce the dilution of the PEG 1000.) The drip-feed could be quickly interchanged to supply various colours, and entry into the feeder tube meant the bulk of the normally colourless PEG 1000 in the bottle remained unstained for future use.

The slope was a Perspex sheet 26 cm wide and 58 cm long, texturally roughened to prevent slippage. It could be held at any desired angle of inclination within a 60 cm × 60 cm × 60 cm Perspex tank and was submerged under water at a nominal temperature of 15°C. The tank was raised off the floor to allow illumination from beneath as well as from the side. The outlet nozzle from the feeder pipe was positioned at the top of the slope, just below the free surface of the water.

THE EXPERIMENTS

Fourteen experimental runs were performed with systematic variations of effusion rate, temperature (and hence viscosity) and slope angle—as summarised in Table I. Where the flow was constrained by the containing wall at the base of the slope, it generally piled up and moved sideways, but this region was not considered in the analysis unless it had a direct bearing on the upslope flow morphology.

In describing the flow morphology of individual experiments, the following observations proved to be useful in a comparative sense, and will be discussed in detail for each case:

i) rate of propagation of the flowfront down the slope;

ii) distribution of different coloured waxes;

iii) thickness and surface features of the solidified flow units;

iv) cross-sectional aspect ratios (height/width);

v) linearity of channel pathways;

vi) branching and side break-outs of channels (including the presence of surface flows and multiple or compound flow units);

vii) roofing/crusting phenomena and tube formation;

viii) thermal and physical erosion phenomena.

Effusion Rate Variation

The first ten experiments were performed on a slope of 15° at varying rates of effusion (Q). In each case the initial temperature of the wax was fixed at 50°C. The rates of propagation of the flowfront for the different effusion rates are plotted in Figure 2.

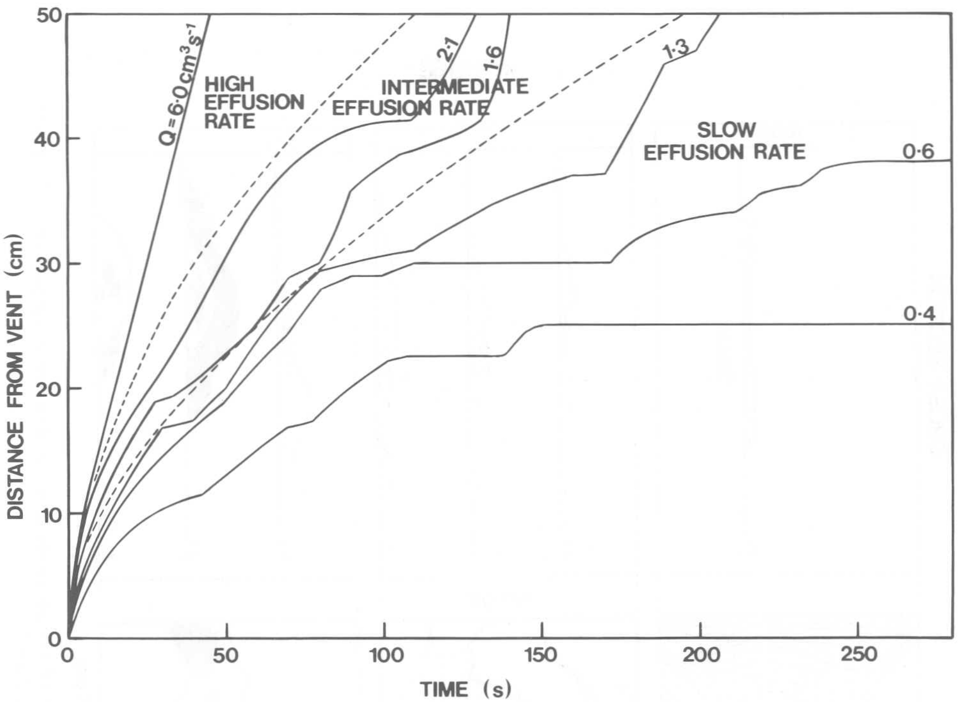

Figure 2 Plot of distance from vent (cm) against time (s) for different values of effusion rate $Q(\text{cm}^3\ \text{s}^{-1})$. In each case the initial temperature was set at 50°C, and the slope angle fixed at 15°. The dashed lines are nominally drawn to separate three regimes of different flow morphology. The high effusion rate regime is characterised by straight, open channels with low cross-sectional aspect ratios. The intermediate effusion rate area is characterised by meandering open channels exhibiting some temporary roof development. The slow effusion rate regime contains those flows which produced compound, tubed units with high cross-sectional aspect ratios.

Three different morphological flow types were distinguished, corresponding to high, intermediate and slow effusion rates, each exhibiting different characteristic patterns.

High effusion rates ($Q \geqslant 3\ \text{cm}^3\ \text{s}^{-1}$). These produced wide ($\approx$10 cm), straight, open channels with low cross-sectional aspect ratios. A typical flow unit is mapped out in Figure 3a and photographically depicted in Figure 4a. The flowfront moved with almost uniform velocity downslope, as indicated by the linearity of the curve for this region in Figure 2. A channel was developed by solidification of the slower moving flow margins, which built up flat, smooth levées at either side of the flow stream, and which increased in width downstream. Some solidification at the flowfront occurred, but this did not hinder the flow, which simply overran any solid obstacles, eventually breaking and pushing them to the sides where they consolidated the channel walls. Fresh molten material was transported along the full length of the channel to the flowfront, and then piled to form a buckled mass at the base of the slope against the confining end wall of the tank. Stained wax, which was introduced after the channel had become established, never contaminated the margins, but flowed directly to the head.

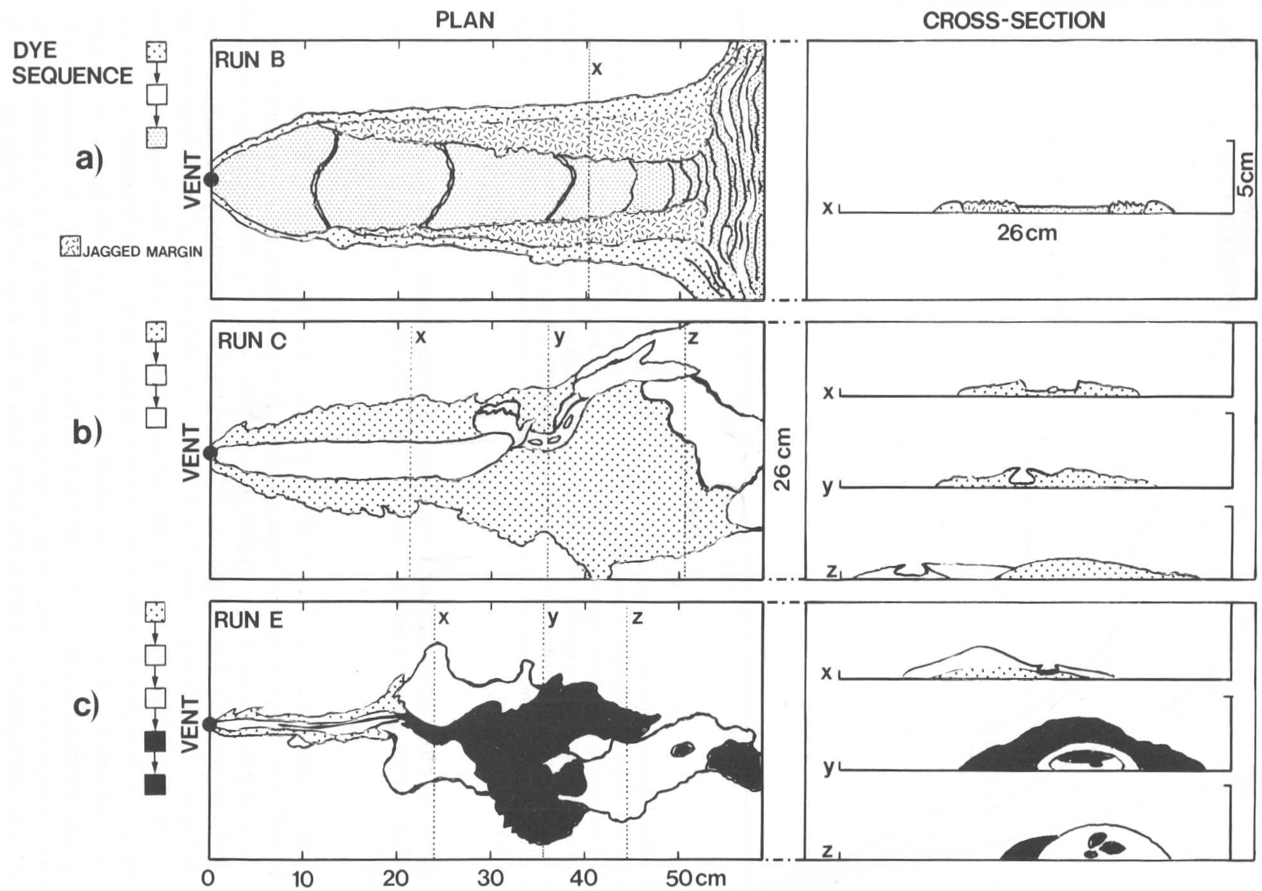

Figure 3 Scale diagrams showing plan and cross-sectional views of the final flow units produced in: (a) Run B (high effusion rate); (b) Run C (intermediate effusion rate); (c) Run E (slow effusion rate). (See Color Plate I).

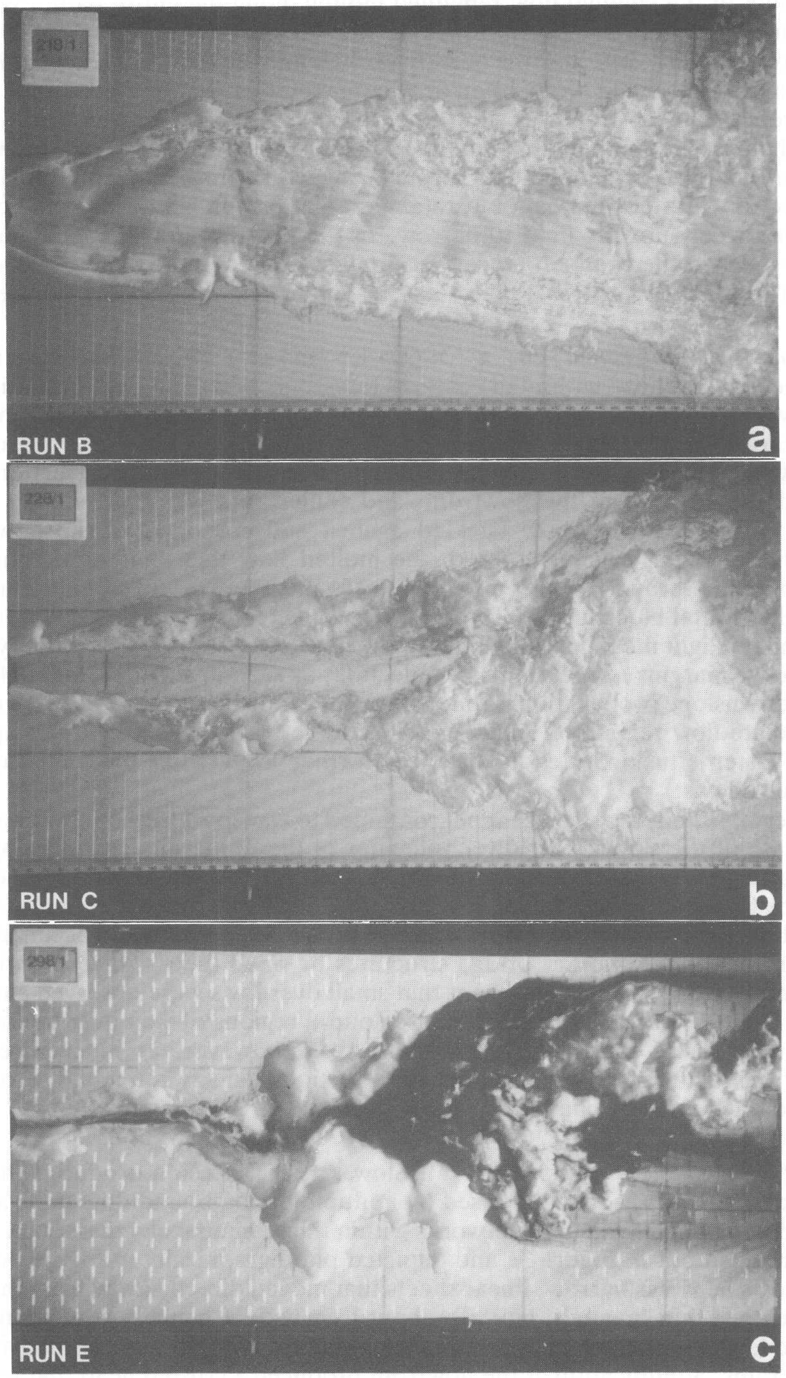

Figure 4 Plan view photographs taken of the final flow units produced in: (a) Run B (high effusion rate); (b) Run C (intermediate effusion rate); (c) Run E (slow effusion rate). The duration of flow in minutes is shown on the clock in each photograph. (See Color Plate II).

The bulk of the channel flow remained molten along the entire path, except for slower moving boundary layers touching the smooth levées. Here some crustal formation was seen, but this was quickly broken into jagged fragments by the fluid motion and then carried away, often to adhere incrementally to the margins further downstream. This detritus was supplemented by irregularly shaped strips of solid material physically sheared off from the solid margins close to the vent. In this way, secondary margins developed with a rough, jagged texture. These marginal zones increased in width downstream but retained a flat profile, and caused the channel containing freely flowing fluid to narrow. In the proximity of the vent, however, erosion widened the channel. Once the supply was cut off, the fluid region quickly froze, cracking into large, flat plates and leaving a smooth, wide central region.

Intermediate effusion rates ($3 \text{ cm}^3 \text{ s}^{-1} > Q > 1.5 \text{ cm}^3 \text{ s}^{-1}$). These flows began in much the same way as those with high effusion rates, but initial channel formation was typically narrower ($\approx$4 cm), with slightly wider but equally flat solid margins. Solidification at the flowfront became more important however, because the momentum of the flow was no longer sufficient to push aside solid obstructions. This retarded the advance of the flowfront, and chilled skin which developed on the surface of the following flow buckled against and consolidated the downslope obstructions. Being briefly retarded, the molten flow then built up in thickness before bursting through or over a weak point in the margins and surging round one side of the frontal blockage. The process then repeated itself further downslope. In this manner, slight meanders and kinks in the flow channel were produced, typically with thicker margins at the points of inflection, as seen in Figures 3b and 4b. The surging downslope propagation is reflected in the gentle-stepped curves shown in the intermediate flow regime of Figure 2. (This mode of advance might also apply to initially faster effusion rates at distances further away from the vent than our apparatus allows.)

Once established, the open channel continued to transport fresh molten wax right to the base of the slope. The lower velocities of these intermediate effusion rates permitted a greater extent of chilling at the surface, but any crust formed was quickly broken by fluid motion and rafted downstream along with eroded marginal material. At bends in the channel, solid rafts adhered to the banks and could accumulate by accretion to form temporary bridge structures or small tubes. Once or twice this constricted the flow to such an extent that small overflows were observed along the channel length, as seen by the different coloured regions of wax over the margins near bends. These break-outs were short-lived, however, as indeed were the constrictions that caused them, and roofed sections quickly re-melted, eroded or collapsed back into the channel.

Slow effusion rates ($Q < 1.5 \text{ cm}^3 \text{ s}^{-1}$). Slow rates of effusion produced the most complex morphologies, characterised by multiple or compound flow units and the formation of meandering tube networks within thick, hummocky masses. A typical unit is mapped out in Figure 3c and depicted photographically in Figure 4c.

The flows began as narrow, linear sheets that moved directly away from the vent, and developed thin channels, typically about 1 cm wide. Channels were bounded by solidified levées with higher cross-sectional aspect ratios than those formed at faster effusion rates. Solidification at the flowfront produced a crusted head that retarded the downslope advance and grew as thin surface crust buckled behind it. Eventually, the flow could not push this crusted mass along and forward motion ceased. The following channelised flow thus increased in thickness but continued to feed molten wax into the interior of the head. This had the effect of inflating the head to form a raised hummock of solidified wax. These features may have close similarities to the lava tumuli of small pahoehoe flows observed on many compound lava fields. Internal pressure thus increased until a break out occurred at some weak point along the margins of the flow or at the flowfront. There then followed a fresh surge of molten wax which repeated this process further downslope. These stop-go cycles are shown in the shallow, multiple-stepped nature of the downslope propagation curves (Figure 2). They were not only responsible for the increased thickness of the flow units, but also initiated a mode of tube formation. Internal tunnels and cavities developed beneath the raised masses allowing the transport of molten wax. Different points of emergence of molten wax from the margins of the hummocks led to a contorted meandering of the flow pathways.

Break-outs of molten wax could occur anywhere along the length of an established tube or channel pathway. This usually signified a constriction or blockage in the tube, leading to a wall rupture further upstream. Once the flow had been diverted, molten material in the closed section could either drain away leaving a hollow tube, or solidify *in situ*. Side ruptures were common and had the effect of widening the compound structure as a new flow ran to one side of a pre-existing unit. In cases where side flows could not circumvent existing massed units, they were seen to back up towards the vent. Surface break-outs also occurred, running along the top of an older flow and increasing the overall height. Each new flow was generally capable of tube formation given a sustained supply, and thus multiple branching of the tube system was possible. In the case of surface flows, these could produce stacked tubes.

An additional mechanism of tube formation occurred in open flow channels. Contact between the molten flow and the cold ambient fluid produced a thin, chilled skin of solidified surface crust. This was progressively broken up by fluid motion and rafted downstream along with solid fragments of eroded bank material. Some fragments re-melted, some disappeared down tubes where they could cause a blockage, while others adhered to points along the bank further downstream, especially at kinks in the channel. Accretionary coalescence of adhered rafts to the channel margins developed to the stage where bridging structures formed over the flow. Compaction of further crustal plates could then extend the bridge back towards the vent, forming an enclosed tube beneath a thin roof. Tubes formed in this manner had a temporary nature, often partially or wholly remelting and collapsing only to reform again, unless they were consolidated and strengthened by subsequent surface flows.

It is important to note here the complex sequential distribution of different coloured wax representing fluid erupted at different times. Repetition of slow effusion rate experiments exhibiting complex morphologies produced quite different patterns each time, highlighting the unpredictability of distribution in compound flows.

Temperature Variation

The effect of varying initial temperature was examined by allowing wax to flow down a 15° slope at effusion rates comparable with those used in previous runs, but at different starting temperatures.

Lowering the initial temperature to 40°C produced two effects. First, the viscosity of the molten wax increased, and downslope propagation was noticeably slower than that for comparable effusion rates at higher temperatures. Second, since the temperature of the wax was now only just above its freezing point, solidification became more pronounced at an earlier stage than before. These two effects led to formation of compound flows with high cross-sectional aspect ratios and tube systems for effusion rates that yielded simple open channel flows at higher temperatures.

Raising the initial temperatures to 60°C decreased the viscosity of the molten wax and thus increased the initial rate of downslope advance. A longer period of flow occurred before the temperature of the head reached the solidification point. Thus for slow rates of effusion, for example, compound flow morphologies began at greater distances from the vent than for comparable lower temperature flows, and were preceded by linear, open channels.

Slope Variation

The effect of varying the slope angle was examined by allowing wax to flow down a 30° slope at an effusion rate and temperature comparable with those which produced compound flows and tube systems along 15° slopes.

This flow began as a thin, broad sheet roughly 5 cm wide moving directly away from the vent at a faster rate of advance than that measured for an analogous flow down a 15° slope. The flow developed into a straight, open channel ≈3 cm wide with raised, solidified margins. Solidification of wax occurred at the flowhead, but was rapidly broken up by the momentum of the following stream to produce irregularly shaped, solid blocks. Rather than arresting the flow, however, this accumulation was rolled downstream along an underflow of molten, surging toes, producing a "conveyor belt" of blocky rubble. Blocks were seen to fall down the advancing face and roll downwards ahead of the molten toes. The flow channel behind this mobile head was continually being crusted over by thin, temporary roofs, only to be dynamically broken up again and rafted away. Rafted fragments were generally much larger than those seen in previous experiments. No tube systems developed, and no side break outs occurred. It appears that a steeper slope angle provides the flow with greater momentum. This enables it to overrun or carry solidified obstructions for longer distances than similar flows on shallower slopes, which succumb to such obstacles at an earlier stage in channel development. The "conveyor belt" motion is reminiscent of aa type lava flows, described in the next section, and is also commonly observed in flows moving down the steep flanks of andesitic volcanoes.

GEOLOGICAL BACKGROUND

Before discussing the experimental results, we give a synopsis of lava flow morphology and tube formation based on field observations.

Much of the groundwork in describing the flow morphology of basaltic lavas has been laid down by Wentworth and Macdonald (1953). Flows generally start as pahoehoe, characterised by smooth, hummocky surfaces, often showing coiled ropy structures. Further from the vent, aa lava flows become more abundant, characterised by a central massive lava layer sandwiched between irregular, fragmented top and bottom layers. The transition from pahoehoe to aa is thought to involve a critical relationship between viscosity and shear strain (Peterson and Tilling, 1980). Aa flows are often fed by open, banked channels transporting the blocky, spinose surface along a conveyor belt of massive, viscous lava. Pahoehoe flows are generally less viscous and move faster, being fed by open channels or enclosed tubes, the flow front advancing by the budding of lobate toes of molten lava at the head. Lava tubes are predominantly confined to the interior of pahoehoe flows, but can also form in aa lavas by break-out at the flow front, as documented by Pinkerton and Sparks (1976) on Etna.

Several mechanisms of tube formation within pahoehoe flows have been observed [Greeley (1971, 1972), Swanson (1973) and Peterson and Swanson (1974)]. We can divide these into two broad types:

i) progressive advancement of lobate toes;

ii) roofing of open flow channels.

The first mechanism occurs at the head of the flow where the semi-solid crust formed at the surface of the lava is ruptured, allowing a pulse of molten lava to surge forward. On exposure to the air, the toe develops a chilled skin which expands as more molten material is fed into its interior. This inflation continues until the internal pressure causes the skin to crack and burst, releasing another surge of molten lava which repeats the process. Assuming the skin of each toe is structurally strong enough, the flow thus advances beneath a series of lobate bulbs forming an enclosed pathway.

The second mechanism of tube formation involves roofing over of an established lava channel, and can occur at any point along the length of the flow. Basaltic lava generally issues from a vent as a wide, thin sheet which quickly develops a semi-solid surface crust. Lateral spreading of the flow is inhibited and stationary levées are formed, due to the non-Newtonian properties of cooling lava (Hulme, 1974). Thus the flow is concentrated into channelways. These channels then self-perpetuate, building up their banks by the accretion of overflow layers, the accumulation of spatter and clinker at the margins, or possibly by downcutting (Sparks *et al.*, 1976). Once established, the open flow channels can roof over by a variety of mechanisms, described by Greeley (1971) as:

i) accumulation of surface scums which are fused together and attached to the stationary channel sides;

ii) accumulation and fusing of flexible mobile crustal plates;

iii) formation of stable, well-defined crusts along both channel sides, which can grow to the centre of the channel and merge;

iv) agglutination of spattered lava to form lateral levées which may arch over the channel and fuse.

In all these cases, an established roof may thicken by accretion from beneath or by overlaying of surface flows, or conversely partially or totally collapse and re-melt. Once a particular flow has ceased, the tubes may drain to varying degrees leaving hollow voids in the flow unit. An important feature of lava tubes is that they provide very effective heat insulation, and permit lavas to be transported great distances from their sources.

DISCUSSION

The wax flows clearly modelled many features of observed lava flow phenomena, and we now discuss the experimental findings.

Distribution

An important aspect of the experimentation was being able to monitor the distribution of wax erupted at different times. Knowledge of temporal relationships between individual units within a compound flow is important for geochemical analyses of lava flows and subsequent conclusions drawn on the compositional zonation of parental magma chambers. Attempts to generalise on such relationships are made difficult by the large number of variables associated with lava flow morphology, especially when one takes into account such determining factors as pre-flow topography. However, the experiments provided specific examples of the range of distribution anomalies likely to be encountered and are useful in emphasising the precautions necessary for valid geochemical sampling. To illustrate this we can consider the wax distribution in three characteristically different flow morphologies, as mapped out in Figure 5.

Straight, open channel flows. Figure 5a shows a single, linear flow unit. The first sequence of released wax was colourless, and established a straight, open channel bounded by thin colourless levées. The wax was then dyed yellow and was transported directly to the confining wall. No yellow contamination of the levées along the length of the channel path occurred. The colour was then changed to green, and the flow continued to pass directly down the channel. During this green sequence, the supply was ceased, and the channel partly drained before completely freezing. Note that this uncovered the channel floor near the vent. Another interesting feature further down the channel is the juxtaposition of young green dye between older colourless levées.

Meandering, temporarily roofed flows. Figure 5b shows a typical meandering flow unit that exhibited temporary bridge structures. Again the first sequence of wax was colourless, and formed a meandering channel banked by colourless levées which were typically thicker and wider along the concave banks at points of inflection. When stained yellow, most of the wax was transported directly to the flowhead, but significantly, some adhered to the channel margins or produced small overflows at bends in the channel. The next sequence of blue-coloured wax adopted much the same behaviour. During this period, the supply was ceased, and again the channel partly drained before the motion decayed. The important point to notice here is the incorporation of younger flow units along selected points of the older channel margins.

Compound flows. When flows permit the establishment of tube systems, the full complexity of chronological ordering within compound flow units becomes apparent.

Figure 5c shows the ability of tubes to carry younger flows beneath pre-existing ones and deposit them further from the source. It also depicts side and surface deposition of subsequent flows to the side of and above older units, and clearly illustrates the juxtaposition of skirting flows round a preformed solidified mass. Note also the progressive upslope deposition of younger units due to tube closures and channel overspills.

Effusion Rate

Variation of effusion rate is considered to be a major controlling factor in basalt lava flow morphology. High rates of effusion produce simple, open channel flows with

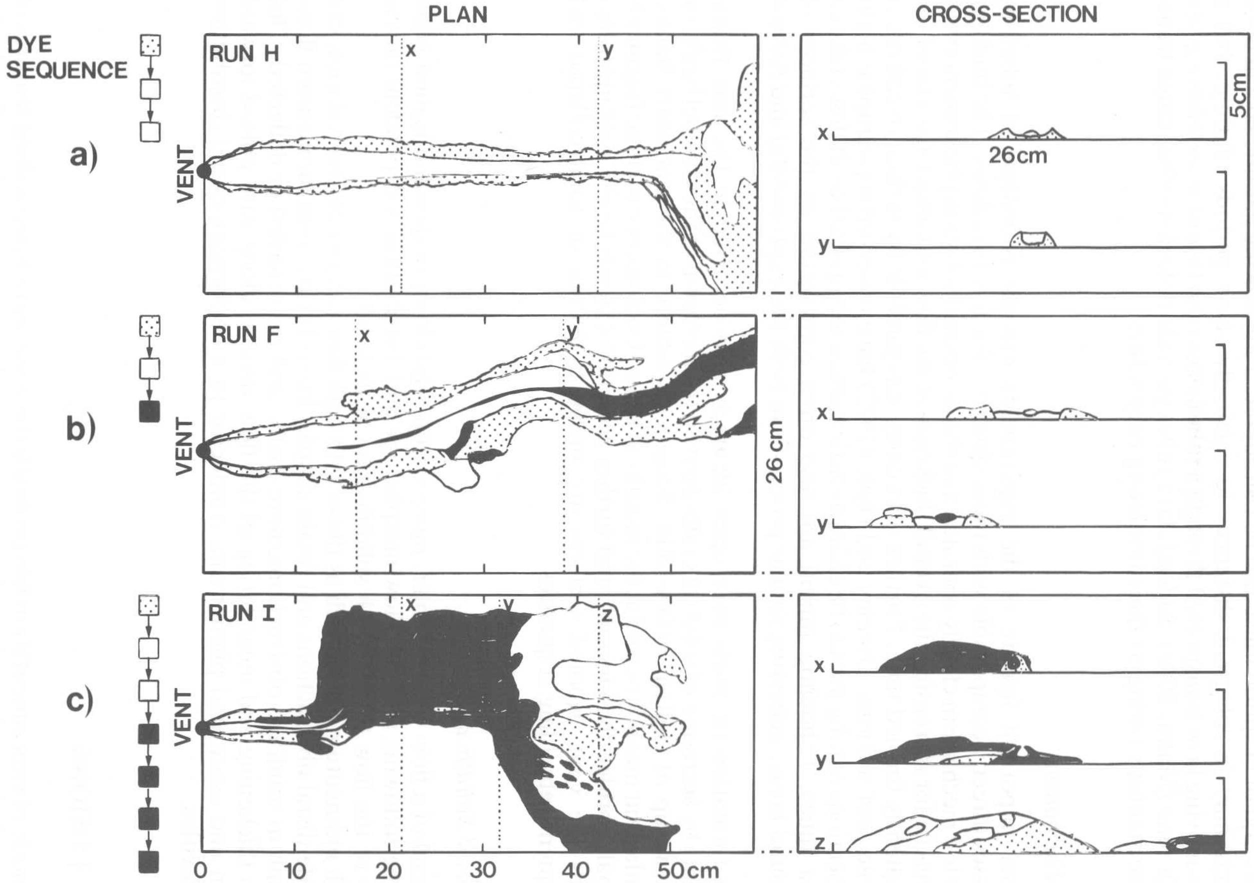

Figure 5 Scale diagrams showing plan and cross-sectional views of the final flow units produced in: (a) Run H (straight, open channel) (b) Run F (meandering, temporarily-rooted channel): (c) Run I (complex tube system). (See Color Plate III).

low cross-sectional aspect ratios. Slow effusion rates yield thicker compound structures with meandering tube systems and high cross-sectional aspect ratios.

The overall length of a flow is also dependent on effusion rate (Walker, 1973), but the duration of eruption must also be considered. Fast-flowing basaltic lava in open channels may travel great distances in relatively short periods of time, but a slower-moving flow transported through a tube system can be just as extensive given enough time (Malin, 1980). Indeed, lava tubes provide notorious long-range transport mechanisms owing to their insulating capabilities.

Tube Formation

Another important feature of the experiments was the formation of tubes by processes directly comparable with those observed for real lava flows. The budding lobate toe mechanism clearly operated and the associated inflation phenomenon was responsible for increasing the overall thickness of the flow unit above the axis of the subsequently formed tube. Further thickening was possible by surface overflows at ruptured roof sections. Greeley and Hyde (1972) have observed topographic highs along sections of tube axes to be characteristic surface features of basalt flows related to lava tubes. Pahoehoe tumuli are also often constructed on the surfaces of compound lavas, indicating similar processes in both the experimental and natural flows.

The formation of roofs over open channels also occurred in the wax flows, generally by accretion of solid wax rafts derived from erosion of the channel banks or the break up of chilled surface skin. Fragments adhere to the stationary banks, particularly at meanders, and at the mouths of tubes. Coalescence of these fragments eventually bridge the channel, and further accretion extends to the roof upstream towards the vent. Roofed sections are prone to partial or total collapse and subsequent rebuilding sequences.

Flowhead Solidification

The head of a flow will be cooler, more viscous and closer to its solidification point than the following stream. Flow morphology and distribution is dependent on the ability of the flow to deal with solidification at its head.

High momentum flows, such as those with high flow rates or on steep slopes, can override distal obstructions and retain simple, linear forms. Low momentum flows succumb to solidified obstructions more easily, and are retarded or deflected. This causes thickening and meandering of the flow stream, along with pulsed forward motion and associated phenomena conducive to tube formation and distribution complexities.

CONCLUSIONS

This mode of experimentation has proved to be illustrative in describing features of flow morphology, chronological distribution and mechanisms of channel and tube formation. The controlled variation of some of the many factors governing flow phenomena has produced interesting morphological changes and provides a means for testing models of lava behaviour based on field observations.

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