

BASALTIC PRESSURE RIDGES: FORMATION AND RELATIONSHIP TO FLOW EMPLACEMENT

E. THEILIG

Department of Geology, Arizona State University, Tempe, AZ, 85287

Pressure ridges and pressure plateaus are common but not ubiquitous surface features on terrestrial basaltic lava flows and may reflect a specific flow emplacement mechanism. Since pressure ridges and pressure plateaus are similar in morphology, occur in association with each other, and probably formed by the same mechanism, they will both be referred to as "ridges" to simplify the discussion. Many of the ridges are large enough to be detected on high-resolution orbital images; therefore, understanding these features could provide a means for interpreting volcanic flows on other terrestrial planets. The objective of this study is to determine the mechanism of pressure ridge formation and how their formation relates to flow emplacement. To provide insight into the timing of ridge formation and mechanism(s) of flow emplacement, detailed field maps were made of parts of two lava flows (Wapi Flow, Idaho, and McCartys Flow, New Mexico) to determine: 1) the relationship of ridges and plateaus to various flow units; 2) the presence or absence of squeeze-ups or addition of new material to the primary flow and their relation to ridges; 3) the orientation of ridges with respect to general and localized flow direction; 4) the association of ridges to other surface features; and 5) the progression of ridge forms.

Pressure ridges and plateaus are associated with flows characterized by multiple-flow units of pahoehoe with a few isolated patches of slab or aa lava, the presence of collapse depressions, and the absence of identifiable lava tubes. Field mapping was initially done in areas where flow direction could clearly be defined, few flow units and ridges were present, and constraints could be placed on ridge formation and flow emplacement. Even though the areas were not as complex as other parts of the flows, they contained all of the general flow characteristics. More complicated areas with numerous flow units, ridges, and plateaus were also mapped to verify the results obtained from the special cases.

The relationship between ridges and various flow units is complex in even the most simple areas. Flow units can be divided into primary and secondary units on the basis of surface texture and occurrence. Primary units exhibit either a smooth and filamented or knobby and lineated surface texture and have a generally consistent flow direction, whereas secondary lava consists of numerous interfingering toes with inconsistent flow directions. The secondary units represent lava which was extruded when either the internal pressure of a flow exceeded the crustal strength or when cracks in the crust migrated downward and intersected the molten lava. In the latter case, the extent of lava erupted was dependent on crack width, the timing of intersection with the lava, and the internal pressure of the flow. No definitive age relationship for primary and secondary lava can be established for the entire flow, since secondary material may either embay or be buried by primary lava from another major flow unit. However, for each main flow unit the primary lava was emplaced first, followed by the break-out and embayment by one or more secondary units. Important observations from the mapping are that ridges can be composed of either primary or secondary units and that each ridge (and, in some cases, series of attached ridges) consists of an individual flow unit or lobe. As such, they are parallel to localized flow direction but may be oblique or transverse to overall flow direction. The relationship between adjacent ridge-containing flow units is complex because secondary material

that erupted from one ridge embays or partly covers an adjacent ridge, indicating some time separation in ridge formation. Therefore, the whole flow is characterized by interfingering flow lobes (each major unit represented by a ridge or plateau) that formed penecontemporaneously.

Several lines of evidence indicate an inflation mechanism for formation of ridges: 1) as observed from the mapping, ridges form the central parts of individual flow units. This is inconsistent with both a collapse mechanism in which ridges are formed by the partial collapse of a flow, and a compression mechanism, in which compressive stress is applied to the flow crust; 2) secondary material erupted from the base of one ridge can extend to the top of an adjacent ridge (this would not be unusual if the secondary flow had a very high velocity; however, since the secondary units appear to be emplaced as tube-fed flows this should not be the case), indicating emplacement of the secondary material at a lower level which was later uplifted; and 3) the break-out of secondary material from the top of the ridge indicates that the interior of the flow unit was under pressure; this would not be consistent with the simple draining of a flow associated with collapse.

From the field mapping a progression of ridge forms has been identified on the basis of size, surface texture, and setting. The smallest ridges are composed entirely of secondary lava erupted as a flow unit from the base of larger ridges. Their surfaces are characterized by short toes and tilted crustal slabs indicating initial emplacement of a thin-crustal flow which may have been toe-fed. The build up of pressure within the initial flow and subsequent inflation is indicated by the uptilted slabs which represent parts of the initial crust that were broken and pushed up when more toes were erupted and flowed down the side of the ridge. Intermediate ridges extend from major ridges (discussed below) and are usually slightly lower than the major features. They exhibit a mixture of surface textures, with secondary textures prominent near the terminus and primary textures near the "source." In many cases, ropes indicate flow direction toward the minor ridge. These ridges formed as flow lobes from the major ridges and advanced by the extrusion of toes and by break-out from underneath a crust. Major ridges form the dominant features on the flow and consist almost entirely of primary pahoehoe with only patches of secondary pahoehoe and aa. These features were probably initially emplaced as relatively thin flow units with some large ropes and were subsequently uplifted.

From the three ridge forms a progression of ridge formation and flow emplacement may be established: Formation of a new flow lobe is initiated by the break-out of toe-fed secondary lava which may then coalesce to form a single flow. Continued eruption of material behind a slowly advancing flow front causes the flow to inflate with subsequent eruption of secondary material. The longer a flow is channeled through this lobe the more it shows transition to the larger primary ridges. The mechanism for the formation of each of the ridge forms is probably the same, and the different forms and surface textures are a function of the duration and volume of material moving in the flow lobe. The longer a flow lobe is active and the higher the volume moving through it, the larger and more dominant it will become.

Results from detailed field studies indicate that pressure ridges and plateaus 1) are emplaced as individual flow lobes, 2) can be composed of primary or secondary material, 3) are dependent on duration and volume of activity within the flow unit, 4) are penecontemporaneous in formation, and 5) are indicative of slowly advancing flows with numerous flow lobes continuously forming and overriding each other.