SPLIT AND SEPARATED TOPOGRAPHY ON EARTH'S SEAFLOOR: A COMPARISON TO BILATERAL SYMMETRY IN APHRODITE TERRA, VENUS; L.S. Crumpler and James W. Head, Dept. of Geological Sciences, Brown University, Providence, RI 02912

Introduction. A variety of topographic and morphologic features of the largest highland on Venus, Aphrodite Terra, have been recently examined and found to have many similarities with the known characteristics of divergent plate boundaries on Earth [1,2]. This comparison and interpretation rests on a range of distinct features and comparable characteristics rather than on any one feature, and on the way in which these features are inter-related in a consistent manner [4]. The existence of a strong bilateral symmetry [2] is an obvious aspect which suggests a divergent plate boundary interpretation. On Earth actual divergent movements and the rates of this divergence are supported by a variety of evidence including: (i) magnetic stripes and their relationships, (ii) seismic activity (transform faults), (iii) radiometric dates of seafloor basalt and paleontological studies of seafloor sediments, and (iv) topographic data such as (a) thermal boundary layer signature, (b) consistent topographic relationships such as the relation of fracture zone topography to the transform offset of linear rises, and (c) split and separated topography.

Of these three criteria, magnetic stripes are the most widely used and accepted proof on Earth, and split and separated topography is probably the least used for demonstrating actual divergent movements; in part this is because of the greater elegance and simplicity of the magnetic stripe method of seafloor dating. But it also reflects the fact that split and separated topographic features have not been previously discussed in any detail in this context for the oceans, probaby because the current knowledge of the topography of the seafloor [3] is limited in many areas. In this paper we examine the evidence for bilateral symmetry of topography in Earth's seafloor, its relationship to the spreading process, and its significance in interpreting the bilateral symmetry observed along profiles across Aphrodite Terra.

Bilateral Symmetry in Seafloor. At least two types of topographic symmetry are known to occur on Earth's seafloor: (i) split and separated individual features, of which two type can be recognized (a) passive, and (b) active, and (ii) rise crest parallel symmetry at both (a) global and (b) local scales.

The first type, split and separated features, refers to anomalies in rise crest topography, such as oceanic plateaus, which are rifted apart on the diverging plate halves. If the feature existed prior to the spreading then it is passively split and the plate boundaries show a puzzle type fit; an example is the rifting and separation of a continental mass, such as South America and Africa. If the feature is linked to the spreading process, such as Iceland, then it can actively form at the rise crest as the splitting is occurring and the plate boundaries show mirror symmetry (parallel). The two types imply two different processes. The active type records variations in the magmatic record and mantle melting behavior. A few examples on the Earth include Iceland, Rio Grande Rise/Walvis Ridge, Corner Rise/Great Meteor Seamount, Tuamotu Ridge/Nazca Ridge, and Kerguelen Ridge/Broken Ridge. Others are less obvious, but well-documented such as the Ceara Rise/Sierra Leone Rise [15] in the equatorial Atlantic (Fig.1). Thus, although not widely recognized, topographic symmetry is present on the seafloor, yet it is generally of lesser amplitude than that associated with linear rises on Venus.

The second type, rise crest parallel symmetry, refers to the tendency for spreading rates and ridge crest volcanism to vary episodically both on a worldwide basis [6] and on a local basis [7,8]. This is a type of symmetry that has not been well studied and simply results from a variation in the depth of seafloor that is more or less parallel to the rise crest axes.

Analysis. Models for the origin of these symmetric features are diverse and the variety of ways in which topographic symmetry can develope through anomalous crustal thickening includes: (i) episodic ridge crest volcanism which can occur as a result of (a) global variations in plate geometry and seafloor spreading rates [6], and (b) local variations in tectonic rift development and spreading cell behavior [7,8,9]; and (ii) anomalous ridge crest volcanism, as exemplified by Iceland and interpreted to represent (a) the interaction of normal ridge crest with a convective plume, (b) local anomalously warm or hot mantle, (c) mantle chemical heterogeneities [10,11,12,13], or a combination [14]. The current stage of understanding of mantle and global processes on Earth does not clearly establish which of these interpretations, or combination of them, is most applicable to the origin of symmetric topography.

Bilateral Symmetry in Aphrodite Terra. In previous reports [2,4] we have illustrated that there are several aspects to the bilateral symmetry across western Aphrodite Terra: (i) a broad and regional symmetry analogous to that associated with thermal boundary layer topography (Fig. 2) as revealed by fitting a curve f{x1/2} to the observed data, and (ii) a smaller scale distribution of symmetrical peaks and troughs analogous to that associated with centrally rifted, split, and separated features as revealed by the residuals when the x1/2 function is removed from the topography [1].

Recently we have extended this analysis to Eastern Aphrodite Terra [5] and showed that bilateral symmetry is characteristic of the entire highland. Profiles in Eastern Aphrodite appear to be smoother, and the smaller-scale symmetry elements are not as prominent. In this respect they are even more similar to the typical simple mid-ocean divergent rises on Earth than Western Aphrodite, where plateaus analogous to Iceland are more common. Such mid-oceanic plateaus are more typical of divergent topographic and volcanic anomalies than normal ocean rises [16].

In general, the map characteristics of Aphrodite Terra show evidence for local circular to oval split and separated type symmetric features [2]. However, when multiple parallel profiles are taken across Ovda Regio [1,2] a distinctly linear ridge can be seen to parallel the symmetry axis both on the north and south side of Ovda Regio suggesting that ridge-crest-parallel type symmetry elements may occur as well as split and separated plateaus.

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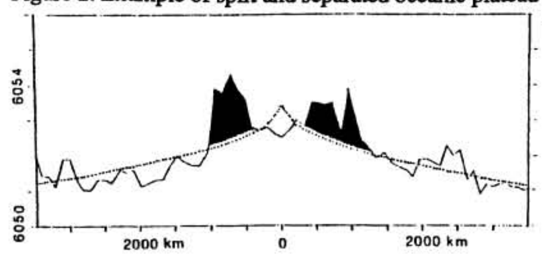
Summary. The origin of split and separated topographic features of the active type can be modeled by locally enhanced accumulation of volcanic materials and increased crustal thickness at an otherwise normal divergent rise crest (Figure 3). In (A) we see the form the topgraphy takes for simple thermal boundary layer case. If volcanic production rates increase at the rise crest, then volcanic accumulation can add to the thermal topography (B), eventually resulting in an Iceland-like plateau (C). If volcanic production rates decrease or cease altogether, then the plateau is split and rifted (D), and the two plateau halves drift apart (E). If the two sides are not in isostatic equilibrium, then as the two halves drift apart they may subside as a result of both isostatic compensation and thermal subsidence (F). This scenario predicts that if Iceland volcanism ceased today, then Iceland would be passively split apart, and ultimately result in two plateaus symmetrically disposed with respect to the Reykjanes ridge.

Conclusions. Bilateral symmetry is a characteristic aspect of profiles across Aphrodite Terra. The exceptional detail of the symmetry is illustrated by the fact that small scale features in the topography appear at the same distance on either side of the central rises [2]. Many of the characteristics of divergent plate boundaries on Earth are analogous to the features of central Aphrodite, and a review of seafloor topography shows that symmetric features are common on Earth. Based on the existing knowledge of the formation of these features on Earth, we interpret the bilateral symmetry of small-scale features about Aphrodite Terra to be the result of finite temporal and spatial variations in volcanic production rates and crustal thickness variations [17] at divergent rises crests on Venus.

References. [1] Crumpler and Head, 1987, J. Geophys. Res., in press; [2] Head and Crumpler, 1987, Science, 238, 1380-1385; [3] Heirtzler, ed., 1985, Report MGG-2, NOAA; [4,5] Crumpler and Head, 1988, LPSC XIX, this volume; [6] Vogt, 1979, Geology, 7, 93-98; [7] Kappel and Ryan, 1986, J. Geophys. Res., 91, 13,925-13,940; [8] Lewis, 1979, Geophys. Res. Lett., 6, 753-756; [9] Shouten and White, 1980, Geology, 8, 175-179; [10] Vink. 1984, J. Geophys. Res., 89, 9949-9959; [11] Brozena, 1986, J. Geophys. Res., 91, 497-510; [12] Duncan, 1984, J. Geophys. Res., 89, 9980-9990; [13] Davis and Karsten, 1986, Earth Planet Sci Lett., 79, 385-398; [14] Oxburgh, 1980, in Hargraves, ed., Phys. Mag. Process., Princeton U. Press, 161-194; [15] Kumar and Embely, 1977, GSA Bull., 88, 683-694; 16] Ben-Avraham, et al., 1981, Science, 213, 47-54; [17] Sotin, et al., 1987, LPSC XIX, this volume.

Figure 1. Example of bilaterally symmetric topography in Western Aphrodite. Thermal boundary layer component shown by dotted line.

Figure 2. Example of split and separated oceanic plateau on Earth (shown in black). After [15].



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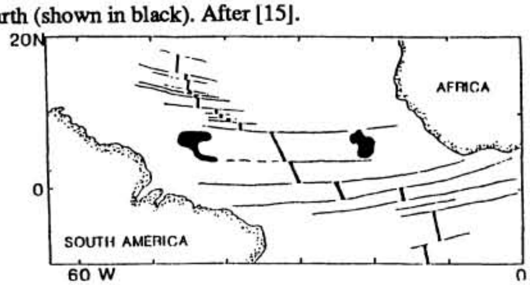

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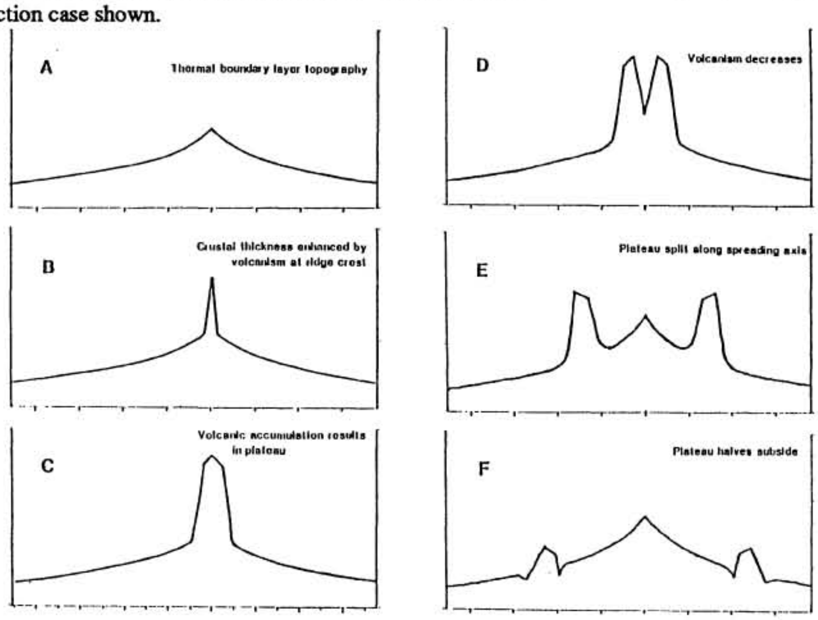
Figure 3. Model for the origin of second order bilateral symmetry features across a divergent plate boundary. Non-isostatic production case shown.



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