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CUSPATE-LOBATE FOLDS ALONG A SEDIMENTARY CONTACT, LOS LUNAS VOLCANO, NEW MEXICO

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BACKGROUND

Cuspate-lobate folds are characteristic of strongly compressed interfaces separating media of differing mechanical competence, with the lobate folds cored by the more competent material and the cuspate folds cored by the less competent material (e.g. Ramsay and Huber, 1987, p. 403). Other commonly used terms for this type of feature include *mullion, fold mullion, and arc-and-cusp structure*. Although cuspate-lobate folds are commonly associated with high-grade metamorphic rocks, their morphology is similar to that of alternating load casts and flame structures in sedimentary sequences. In addition to having geologic significance as indicators of both competence contrast and shortening direction, cuspate-lobate folds are also amenable to theoretical and experimental analysis.

Ramsay and Huber (1987, pp. 392-393) maintain that cuspate-lobate folds form only along interfaces separating media of low viscosity contrast, perhaps less than an order of magnitude. Smith (1975, 1977) and Fletcher (1982) analyzed the growth of instabilities along interfaces separating both linear and nonlinear fluids, and concluded that, although so-called mullion instabilities have small growth rates, mullion growth is enhanced in nonlinear fluids. One important conclusion of such analyses is that no first-order dynamic instability, which would maximize the growth of structures with a preferred wavelength, will develop between two semi-infinite fluids. Instead, there is only kinematic amplification of pre-existing perturbations alng the interface. Johnson and Pfaff (1989) provided a detailed geometric analysis of the waveforms necessary to produce different forms of folds, including-cuspate-lobate folds, and showed how cuspate-lobate folds might evolve from sinusoidal folds in linear viscous multilayers subjec[1]ted to shortening of 6-8 %. Recent experimental work with strain-softening silicon putty models (Sokoutis, 1990) has shown that cuspate-lobate structures grow rapidly along a single interface separating two semi-infinite fluids with low viscosity contrast, but again with no preferred wavelength, subjected to shortening greater than 10%.

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OBSERVATIONS

A series of exceptionally well developed cuspate-lobate folds is exposed along a sedimentary contact at los Lunas volcano (Fig. 1). Below the contact is a buff to orange alluvium composed of silt and fine sand, with no distinct bedding. Above the contact are a 1-2 cm thick white ash, a 10-15 cm thick gray tephra ranging in size from sand to granule, and a coarser orange [sic] tephra up to 1 m thick. Much of the less-resistant alluvium beneath the contact has been removed by erosion, showing that both cusps and lobes extend at least a meter back into the outcrop; therefore, these folds can be analyzed as two-dimensional structures. Most cusps in the sequence point downward, suggesting that the finer-grained alluvium was generally the more competent material during deformation; however, a few very low-amplitude cusps do point upward. The lobe portions of folds are somwhat flat, similar to a theoretical pattern consisting of a positive first waveform and a negative second waveform (Johnson and Pfaff, 1989, p. 128). Cusp amplitude and peakedness both decrease along the ash and tephra contacts above the alluvium. In addition to the prominent cuspate-lobate folds, the interface is also folded into a gentle syncline with a wavelength on the order of 10^2 m, and cut by two small thrust faults with shortening of 0.19 and 0.48 m. The distribution of 54 fold wavelengths, measured by stretching a tape between adjacent cusps, has a fairly strong central tendency (Fig. 2), with an arithmetic mean of 1.78 m and a standard deviation of 0.76 m.

CONCLUSIONS

The existence of both cuspate-lobate folds and small thrust faults shows that the sedimentary contact described in this paper has been shortened significantly, and cusp orientation shows that the alluvium was from one to ten times more competent than the volcaniclastic sediments during deformation. If mass was conserved during shortening, the thickness of the stratigraphic section must also have grown proportionally. Although measurements of arc-length are appropriate for preferred wavelength studies (Sherwin and Chapple, 1968), straight-line cusp-to-cusp measurements are much easier to collect and provide a useful first approximation of wavelength distribution. Because neither theory nor experiment predict the existence of a preferred wavelength for cuspate-lobate folds along a single interface, we are faced with two alternative explanations for our observation of somewhat uniform wavelength. First, the cuspate-lobate folds could represent the amplification of pre-existing perturbations along the interface, for example ripple marks. Second, it is possible that a preferred wavelength evolved because the sediments on one or both sides of the interface behaved as finite layers, for which dynamic instabilities will arise. Smith (1975) for example, suggests that many cuspate-lobate folds along single interfaces in the field are actually the erosional remnants of a finite layer with cuspate-lobate folds along both interfaces. At present, meager knowledge of the depositonal and deformational history of these sediments does not allow either of these explanations to be favored over the other. It is hoped, however, that detailed mapping and mechanical analysis will provide a better understanding of the exceptional structures at Los Lunas volcano.

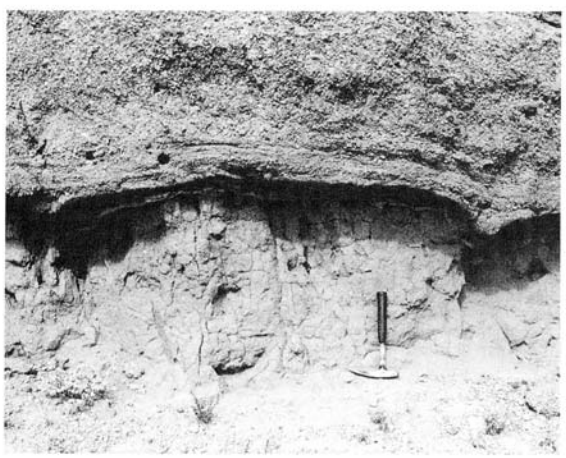

Figure 1. Example of cuspate-lobate folds developed along interface between fine-grained alluvium (lower) and ash-tephra sequence (upper) at Los Lunas volcano. Note changes in cusp amplitude and peakedness along bedding surface in volcaniclastic sediments. Hammer handle is approximately 33 cm long.

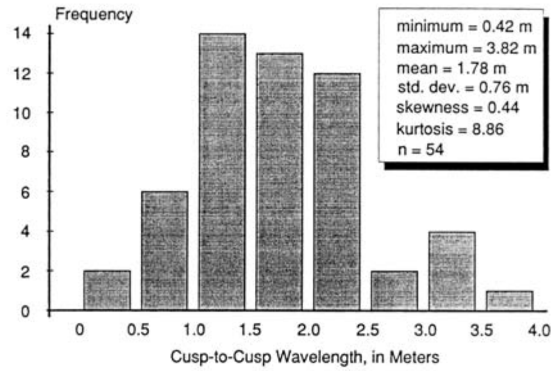

Figure 2. Histogram and sample statistics of cusp-to-cusp wavelengths of 54 cuspate-lobate folds measured at Los Lunas volcano.

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