EUROPA'S SOUTH POLAR REGION: RECONSTRUCTION OF THE SEQUENTIAL RESURFACING HISTORY.
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Europa appears to be extremely active geologically, to the extent that the surface that existed several tens of millions of years ago has been entirely reprocessed since then [1]. Some studies have suggested that the character of the resurfacing has changed during this time, reflecting long-term changes in the geophysics of Europa [2]. According to such interpretations the ice crust of Europa, which overlies a global ocean, has undergone a systematic global thickening, perhaps caused by long-term orbital evolution. A trend toward a thicker crust would be consistent with work by Greenberg [3] that suggested the Galilean satellites are currently evolving away from orbital resonance, so that their orbital eccentricities, and hence tidal heating are decreasing. The timescale for such orbital change is consistent with the period over which the present surface of Europa has formed.

The geological evidence cited for systematic change is a perceived evolution in the style of active resurfacing processes. Resurfacing has been dominated by two major categories of processing (ref Greenberg reviews): tectonics and formation of chaotic terrain. According to those who argue for systematic change, tectonic effects dominated earlier, while formation of chaotic terrain did not become important until more recently [e.g. 2], and the perceived trend is interpreted as evidence for a thickening of the crust.

There are problems with that scenario. First, it is not clear that formation of chaotic terrain necessarily indicates a thicker crust. On the contrary, chaotic terrain may be an indication of relatively thin ice if it is produced by modest local or regional concentrations of tidal heat [4,5,6]. Thus, if chaos is a recent phenomenon, it would suggest a thinning of the ice rather than a thickening.

A second problem is that the case for systematic change over time depends on mapping activities that may depend on subjective taxonomic definitions, which is a particular concern for Europa where ground-truth data are lacking and where observational selection effects are significant [7,8]. Terrain classifications used in the geological mapping of Europa have been defined on the basis of their appearance in images taken under diverse conditions, which can affect the interpretation of maps based on such schemes. Observational selection effects are especially significant for chaotic terrain where older or small patches are harder to recognize, a problem that can be mitigated in the few sites where high-resolution imaging is available.

Detailed studies of such sites provide an alternative to the geological mapping of large-scale regions to see whether there are any indications of systematic change in geological processes. The advantage is that many of the observational selection effects that can skew regional mapping are avoided, and a record of nearly everything that happened to the surface, and the order of the events, is available. The disadvantage is that, with the limited Galileo image set, high-resolution means that one sees only a limited locale, which may or may not be typical of the surface as a whole. Thus, both approaches have shortcomings, but used together they can provide complementary evidence.

Here we report on the sequence of diverse resurfacing events in the region near the south pole imaged during Galileo orbit E17 at resolution 40 meters per pixel. This region is defined by a line of five image frames covering an area roughly 45 km x 200 km and displays clear evidence of events that represent most of the resurfacing processes that have been active on Europa. The southwesterly three image frames of this mosaic are dominated by a relatively recent episode of chaos formation, which evidently disrupted an earlier tectonic terrain and hides the preceding historical record. Therefore, we concentrate on the northeastern half of the area, shown in Fig. 1 with some major features marked, including chaotic terrain that formed at various epochs, simple cracks, ridges, dilation bands, and locations of strike-slip displacement. The effects of each modification event on the previous terrain are generally quite apparent, allowing reconstruction back in time through a sequence of steps.

Our reconstructions show that between the times of formation of the unit labeled *Young Chaos* and that labeled *Old Chaos*, more than half of the area under study was resurfaced by the various processes. Thus, at least in this limited area, and over the period of time represented by the reconstructions, there has been no systematic change in the role or character of chaotic terrain formation.

Between the formation of the *Old Chaos* and the *Young Chaos* units, several generations of tectonic processing occurred in this area. The *Old Chaos* was crossed by the *Old Ridge* (red crossing white *Old*

Chaos in Fig. 1) which was then cross-cut by a very wide smooth band. Then the *Old Chaos* was crossed by the *Ridged Band*, which underwent strike slip and the *Ridged Band* was then cross-cut and sheared apart in several places (the green units in Fig. 1 reconstruct as a single lineament). After that the *Big Bands* unit formed and dilated, accompanied by considerable strike-slip along the eastern side. Later, the *Big Bands* were cut by the arcuate ridge at the upper right in Fig. 1 and by ridge R3, both of which offset the *Big Bands* by shear. Still later, several simple cracks (e.g. K2 and K5) crossed the area. The *Little Puddle* (at the intersection of K2 and K5), probably a thermal rather than tectonic feature, must have formed in this same time frame, because one crack (K5) was destroyed by it and another (K2) cut across it. The *Chaos Blob* and the *Big Puddle* formed earlier than the cracks, but their fresh appearance suggests not much earlier. Still more recently than those simple-crack formation events, the large raft containing substantial parts of the Ridged Band and the Big Bands drifted westward (with slight clockwise rotation) during formation of the *Young Chaos* area. Only after that did the arcuate Ridge R1 form, accompanied by substantial strike-slip along its length.

During the period of time spanned by the events from the formation of the *Old Chaos* to the *Young Chaos*, approximately 50% of the area under investigation was resurfaced by all of this thermal and tectonic activity. Thus, to the extent that this small region is typical, we are looking back through a substantial fraction of the history of the surface of Europa. In fact, most of the earlier tectonic processes are visible, including large numbers of double ridges and dilational bands that cover most of the area other than what we have found to have been created since the *Old Chaos*.

There is no evidence at this site of a systematic change in the character of resurfacing. Chaotic terrain was created not only relatively recently, but also long before much of the tectonic resurfacing in this area. On Europa, in general, chaos formation seems to have occurred occasionally, from time-to-time and place-to-place going back as far as we can see in the geological record.

References: [1] Greenberg, R., and Geissler, P. (2002) *MAPS 37*, 1685. [2] Figueredo, P., and Greeley, R. (2004) *Icarus 167*, 287. [3] Greenberg, R. (1982) In *The Satellites of Jupiter*, U. Arizona Press, Tucson, 65. [4] Greenberg, R., et al. (1999) *Icarus 141*, 263. [5] O'Brien, D.P., et al. (2002) *Icarus 156*, 152. [6] Thomson, R.E., and Delaney, J.R. (2001) *JGR-Planets 106*, 12355. [7] Hoppa, G.V., et al. (2001) *Icarus 151*, 181. [8] Greenberg, R. (2005) *Europa, the Ocean Moon*, Springer-Praxis.

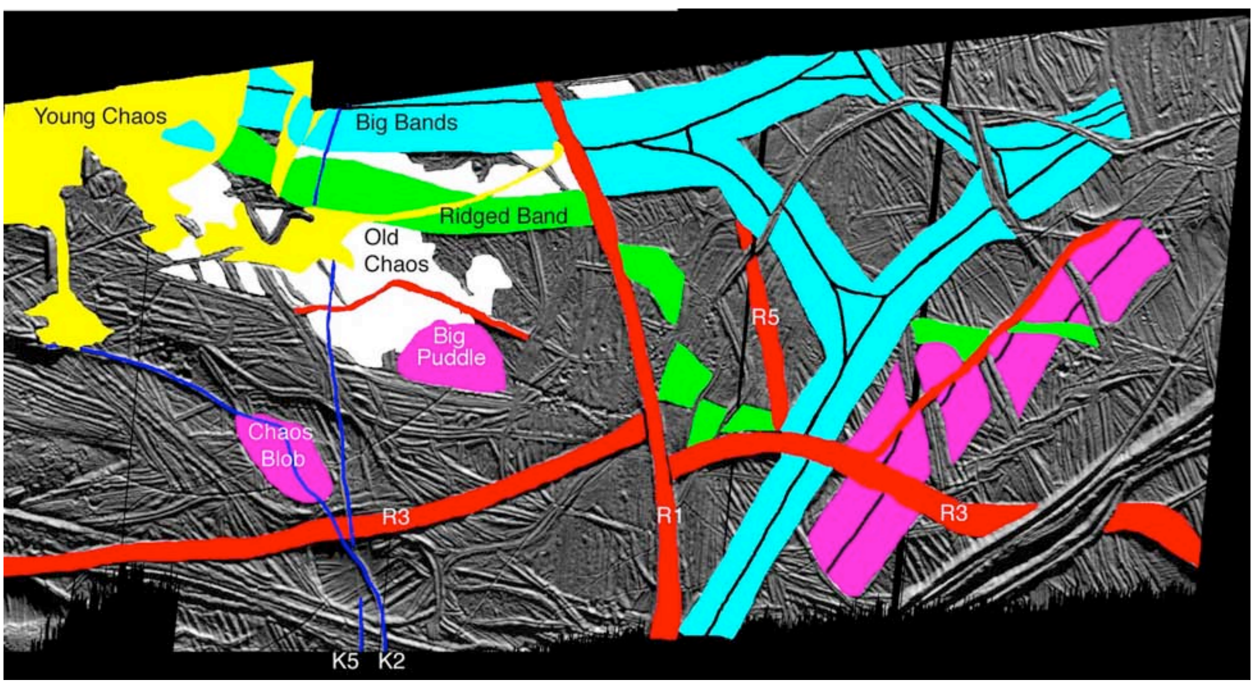

Figure 1