

STRATIGRAPHY OF SMALL VOLCANOES AND PLAINS TERRAIN IN VELLAMO PLANITIA, VENUS

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Objectives: (1) to analyze the relationship between fields of small volcanoes and plains terrain on Venus by using the tool of geologic mapping; and (2) to use stratigraphic relationships interpreted from the mapping to test theories of the geologic evolution, formation and resurfacing of the plains terrain. **Results:** Newly defined plains unit in Vellamo Planitia contains all of the small volcanoes in the area, is well-defined with consistent stratigraphic relationships, and may represent a potentially widespread period of edifice-building and a stratigraphic marker unit.

INTRODUCTION The plains terrain on Venus covers approximately 80% of the surface [1]; and the mechanism of formation, total crustal contribution, and age (or range of ages) represented by the plains is presently uncertain or unknown. Fundamental questions and theories regarding the thermal evolution of the planet [2,3] can only be tested by an understanding of plains stratigraphy. While the Venus plains can be assumed, by analogy with Moon and Mars, to be volcanic in origin with subsequent surface modification by tectonism, impact cratering, and aeolian processes [4-8], there is a paucity of individual volcanic centers, particularly large volcanic edifices, occurring within the lowland plains terrain [9,10]. The volcanic features that do commonly occur are lava channels [11,12] and clusters of small, predominantly shield-type, volcanoes [1,18]. These volcanoes are the most abundant geologic feature on Venus, and were initially recognized on Arecibo and Goldstone Earth-based images [13,14] and first examined in detail using the Venera 15/16 data [15-17]. These clusters of volcanoes may be similar to volcanic "fields" in the terrestrial volcanological sense of the term [18]; and they appear to have some volume of volcanic flows, or possibly a small component of pyroclastic material [1], covering a larger area in association with each "field" of edifices. Although lava channels appear to be related to the mechanism of formation of some plains terrain, there is embayment and stratigraphic evidence for variations in age of local fields of small volcanoes and associated plains units. A major question that is the focus of the VMAP research reported here is the relationship between material extruded or intruded in association with these "shield fields" and the formation or resurfacing of the plains terrain with which they are associated.

DATA AND PRELIMINARY ANALYSIS Venus quadrangle V12, Vellamo Planitia, centered at 37°N and 135°E, was selected for mapping on the following basis: (1) presence of a large number of small volcanoes; (2) occurrence of the small volcanoes in association with lowland plains terrain; and (3) low abundance of large-scale volcanic or tectonic features that might complicate the geologic evolution of the surface and obscure stratigraphic evidence. Vellamo Planitia Quadrangle is situated at the intersection of major terrain units of geologic significance. The western half of the quadrangle consists of a large number of clusters of small volcanoes and isolated patches of tessera, while the eastern half consists of extensive ridged plains with 2 previously identified coronae [19] and ridge belts. Four possible stratigraphic models can be tested on the basis of stratigraphic relationships interpreted from geologic mapping: (1) the small volcanoes are the source of flows that form or resurface the plains; (2) the small volcanoes and the plains have been formed simultaneously; (3) the small volcanoes predate plains terrain; and (4) the small volcanoes postdate the plains. **Small Volcano Plains Unit.** The portion of the quadrangle shown in Figure 1 is a critical area where abundant clusters of small volcanoes and extensive plains units intersect; and the stratigraphic relationship between tessera, small volcanoes and plains can be determined. Five geologic units occur in this area. As has been reported by other workers in other areas, tessera (Complex Ridged Terrain) appears to be the oldest stratigraphic unit in the area. Remnants of tesserae are embayed by three plains units. The oldest of these plains units appears to contain all of the small volcanoes in the area. This unexpected and newly defined plains unit has been informally named "Small Volcano Plains" unit on the preliminary map. It is a discrete geologic unit with well-defined contacts and consistent stratigraphic relationships. This was an unexpected result of the mapping. Prior to detailed mapping, it was assumed that local clusters of small volcanoes would show relative stratigraphic and contact relationships with small areas of plains. However, all of the small volcanoes in V12 occur on this distinct and mappable plains unit. The "small volcano plains" unit overlays and embays tesserae throughout the mapped area; and it is overlain by two units of younger ridged plains that contain few volcanic edifices. Where small volcanoes occur within the ridged plains units, they are clearly isolated outliers of the small volcano plains which have been embayed and surrounded. The two ridged plains units (Pr₁ and Pr₂) are distinguished by difference in radar backscatter and embayment relationships along contacts. However, the orthogonal system of small-scale ridges that occur in both units crosses the contact boundaries without showing a systematic change. This may indicate that the difference in radar characteristics of Pr₂ simply reflects a resurfacing event of Pr₁ or that the small-scale ridges represent a continuing or late-stage deformational process. Ridge-belts, however, occur only in the youngest ridged plains unit and do not cross the "small volcano plains". Altimetry profiles show that the younger ridged plains are locally topographically higher than the older "small volcano plains".

Implications. Preliminary results from mapping Vellamo Planitia Quadrangle indicate that the small volcanoes in this region are uniquely associated with (and are probably the source of) a distinctive plains unit that postdates tessera terrain and predates the more extensive ridged plains terrain. The "small volcano plains" unit mapped in this area is a potential stratigraphic marker. It is well-defined regionally and its temporal relationships with adjoining units are consistent; however, its total areal extent and relationship with other areas of small volcano concentration is unknown. Continuing analysis will address the following: What is the nature of the "small volcano plains" material and emplacement? What are its distinctive characteristics in the Magellan physical properties data sets? What are the detailed characteristics of the individual small volcanoes that occur within this unit? Does the unit represent a regional or

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discovery. For example, the hit book and movie Jurassic Park (and every child's fascination with dinosaurs) were used as a basis for a 2-day teacher's workshop held in August and based on the science issues of "Jurassic Park". Researchers in biology, paleontology, geology and mathematics gave presentations on chaos theory, DNA and genetic engineering, dinosaur physiology, mass extinctions, the Jurassic Period, and theories of dinosaur extinction. The full two days began with breakfast and a field trip to one of the largest excavated dinosaur trackways in the world, located in nearby Connecticut, and concluded with lengthy discussions over pizza after a special showing of the movie Jurassic Park. We had to limit the number to the first 40 teachers to enroll - a number reached just two days after our mass mailing went out - and they included teachers from all grade levels and from schools in every part of Rhode Island. They gave up 2 days of their summer vacation but took home lots of information, hand-outs, copies of Earth Magazine, and ideas about teaching science in their classrooms this fall.

This approach, sharing "hot-topic" research in the context of entertainment, rather than producing specific curriculum products, found favor with the teachers. Their evaluations were uniformly enthusiastic: "I liked this well-developed, innovative approach, I think this format is a pleasant change of pace from the usual teacher workshop fare". "I enjoyed using a book I had read to learn about new research". "I found the information useful for my own background in designing and teaching a dinosaur unit". "Congratulations on presenting an outstanding opportunity to RI educators...this is the kind of non-text learning experience that can keep science fresh for teachers and their students."

STUDENT TO STUDENT Public schools in economically disadvantaged urban neighborhoods frequently have no science resources. We have set up "partnership" programs with several such elementary and middle schools in Providence. Our graduate and undergraduate students have visited and worked with every grade level and every class in these partnership schools - showing the kids what is possible. Teacher's evaluations noted that "the kids were so excited they could barely contain themselves and talked about the visit for weeks after" and "the Space Grant visitor was so enthusiastic about the subject matter, she captivated the children"... "this presentation allowed the children to extend their knowledge and get answers to their questions"... "this gave the students a positive attitude toward both the material presented and those involved in science!"

Student to student is particularly effective when the visitor becomes a role model. Our women graduate and undergraduate students have taken part in 3 math/science workshops for middle school girls. We funded a group of African-American and Hispanic middle school children from economically disadvantage neighborhoods to visit Brown University science departments for hands-on fun every day for a week during the summer. But, more importantly, we were able to provide mentors from among our graduate fellows who accompanied the kids every day, ate lunch with them, and shared their experiences and reasons for studying science.

An urban elementary school with a high population of Spanish-speaking children became a focus for one of our Hispanic undergraduate scholars. She put together a program in association with the bilingual teachers at the school and has visited the classrooms once a week for a full year presenting a range of science topics and exercises in both English and Spanish. According to their teacher, "this has been a wonderful experience for the children - they look forward to her visit each week and come prepared with information and questions...not always just about science!"

SPECIAL FOCUS With teacher-input we have offered a range of short-courses for several individual schools or classrooms. For example, an after-school science club in one school planned an entire Mars mission with the weekly visits of our engineering graduate fellow and geology undergraduate scholar. One of several mini-courses we designed and presented was requested by a 6th grade teacher on "Using math to solve real science problems".

Our most ambitious project to date has been a 3 year association with all 20 elementary schools of the Warwick RI Public School System and their science teachers and science supervisor. The Warwick school system is one of only two in the country with designated science teachers for grades 1-6 in all elementary schools. In conjunction with the "Space and Planets" section of their science curriculum, our graduate and undergraduate students have given presentations to all 3rd through 6th grade science classes. Each year we have face-to-face contact with approximately 6400 Warwick children and 400 Warwick classroom teachers in a 2-month period. The children then choose a space science topic, research it, and produce an individual or group poster or story board (with video) depending on their grade level and in association with the school art teachers. In 1992, 45 children were presented with gold medals from RI Space Grant in an award ceremony covered by the local newspapers and TV news; and 2 children and 4 teachers were awarded trips to the Smithsonian Air and Space Museum and Goddard Spaceflight Center. The winners for 1993 will be announced soon, and a gallery showing of their posters is planned. This sustained involvement in association with strongly supportive and interested science teachers has made it possible to track science testing scores for children in the Warwick elementary schools. They have increased by an unprecedented 11 points since the start of active involvement by the RI Space Grant program in "using space and art to teach science".