Manteniendo la orientación de los ejes principales (dirección de compresión N55) se pasaría desde fallas inverso-direccionales (1) a desgarres inversos y desgarres puros (2), para terminar en desgarres normales (3). Lo que podría indicar un mayor predominio de las compresiones en relación con áreas situadas más hacia el W, aunque, dada la presencia de diques y la naturaleza de la distensión radial fianl, cabe considerar que esta zona queda también afectada por la etapa final del «ciclo Hiendelaencina». De este estudio se puede deducir que la mayor parte de las direcciones de fracturación alpinas (C y D en la etapa ibérica y A y B en la Guadarrama) fueron previamente tardihercínicas.

Conclusiones

El análisis de la fracturación en los macizos paleozoicos de la Rama Aragonesa de la Cordillera Ibérica permite establecer una secuencia evolutiva durante los tiempos tardihercínicos.

Las orientaciones de los diques de cuarzo, barita y rocas volcánicas estudiados mediante el diagrama e/K' indican la presencia de cuatro familias: N130 E (A), N150 E (B), N20 (C) y N90 (D), que evolucionan dentro de una secuencia inversa, desde fallas inverso direccionales a desgarres inversos y desgarres puros para finalizar como desgarres normales, dentro ya de la secuencia normal. La dirección de compresión estaría situada durante todo el tránsito según los N55. La etapa es asimilable a la «fase Hiendelaencina» descrita en el Sistema Central.

Estas direcciones de fracturación son activas durante la tectónica alpina, a la que fueron incorporados los macizos paleozoicos, encontrándose en ellos fallas con direcciones similares a las distintas etapas compresivas y distensivas alpinas.

El presente trabajo ha sido financiado por el proyecto núm. 3.394. C.A.I.C.Y.T.

Referencias

Angelier, J. Mechler (1977): *Bull. Soc. Geol. Fr.*, 19, 1309-1318.

Capote, R.; De Vicente, G.; González Casado, J. M., y González Vallejo, L. (1986): *1^er^. Simp. Fenómeno Sísmico* (Murcia). 1-12.

Conte, J. C. y Lago, M. (1985): *II Congr. Estr. Paleont. Pérmico Triásico Esp.*, 35-36.

De Vicente, G. (1987): *Meeting stresses and fault systems.* Swansea, U. K.

De Vicente, G.; Martínez, J.; Capote, R., y Lunar, R. (1986): *Estudios geol.*, 42, 23-31.

García Gil, E. (1985): *Estudios metalogenéticos de las mineralizaciones de cobres grises de Alpartir (Zaragoza).* Univ. C. Madrid.

Guimerá (en prensa): *Bol. Geol. y Minero.*

Lötze, F. (1929): *Abh. Ges. Wiss. Gott. March-Phys.* K1, 1-320.

Muñoz, M.; Ancoechea, E.; Sagredo, J.; Peña de la, J. A.; Herrán, F.; Brandle, J. L., y Marfil, R. (1985): *Compte Rendu*, 3, 17-52.

Herrández Samaniego, A.; Aragonés, E.; Aguilar, M. I., y Ramírez del Pozo, J. (1980): *Mapa Geol.* MAGNA núm. 410. IGME.

Osacar, M. C. y Besteiro, J. (1984): *I Congr. Esp. Geol.*, 2, 613-626.

Simón Gómez, J. L. (1982): *Compresión y distensión alpinas en el sector centro-oriental de la Cordillera Ibérica.* Tesis Doct. Univ. Zaragoza.

Recibido el 10 de febrero de 1987
Aceptado el 17 de febrero de 1987

Ridge distribution and fluidized crater occurrence on Mars

A. F. Chicarro. Departamento de Geología. Museo Nacional de Ciencias Naturales. C.S.I.C. José Gutiérrez Abascal, 2. 28006 Madrid.

ABSTRACT

The planetwide distribution of Martian ridges reveals that compressive stresses have occurred well beyond the Tharsis-dominated hemisphere. Regions of high ridge density show a large number of fluidized craters, whose morphology indicates the low viscosity of the target material. Ridge formation has occurred in regions and at times of low viscosity, in response to compressive stresses.

RESUMEN

Las crestas de Marte son estructuras que responden a una tectónica compresiva. Las regiones con gran densidad de crestas muestran también una abundancia de cráteres fluidificados, cuya morfología refleja la baja viscosidad relativa del material impactado. La formación de crestas ha tenido lugar en regiones y épocas de menor viscosidad, bajo la acción de fuerzas de compresión.

Chicarro, A. F. (1987): Ridge distribution and fluidized crater occurrence on Marz. *Geogaceta*, 2, 17-19.

Key words: *Mars, compressive tectonics, ridges, fluidized craters, target lithology.*

Introduction

Like on the Moon and Mercury, ridges on Mars are generally believed to reflect compressive stress fields (Phillips *et al.,* 1980). These structures are most easily recognizable on smooth plains of volcanic origin (fig. 1), although previous studies have noted their occurrence plenetwide (Gifford, 1981). Viking images clearly show that all highly ridged areas display an unusual number of fluidized craters. The geographical association of these two features suggests that compressive stresses are more easily expressed as ridges, on low viscosity materials.

Ridge distribution

Over 16000 Martian ridges have been identified, mapped, classified and digitized in order to provide a large computer-based data set for analyzing regions where compressive stresses have ocurred. These recent systematic studies (Chicarro, 1983) have revealed a broader pattern than previously recognized and specially ridge occurrence in the old terrains (Chicarro *et al.,* 1982). Also, the distribution and orientation of martian ridges have been controlled by the stresses related to the formation of major impact basins (Chicarro *et al.,* 1984 and 1985), in addition to regional tectonic effects (Maxwell, 1982).

Ridges are located on most geologic terrain types, with the notable exceptions of the most recent volcanic units of Tharsis, the lightly cratered northern plains and the polar terrains. These regions have been either unaffected by the stresses responsible for ridge formation or more likely, buried by later deposits. The highest ridge densities occur, however, in the plain regions and in particular in the «ridged plains» unit. But major ridge systems also occur in other geologic settings, such as the plateau plains and the southern highlands. The distribution of major ridge systems clearly shows that regions well outside the Tharsis-dominated hemisphere have undergone extensive deformations. The local occurrence of intercrater plain ridges within the highlands is probably related to ancient impact basins (Schultz *et al.,* 1982).

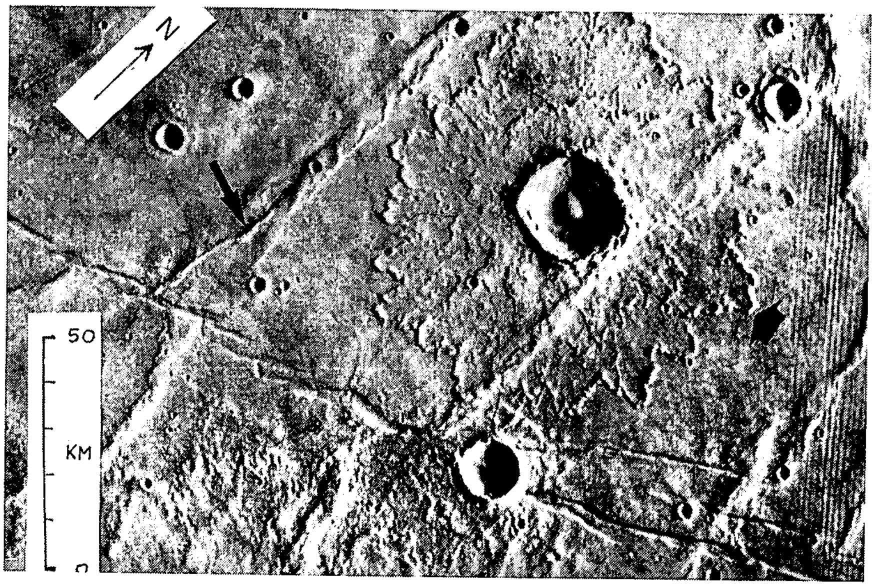

Fig. 1.—Ridges and complex fluidized crater in the Coprates region of Mars (NASA Viking Orbiter frame 6IO A OI)

On Mars, compressive stresses do not only affect the upper layers, but the whole lithosphere because of the large variety of geologic terrains that exhibit ridges. However, the presence of subsurface volatiles (trapped ice near the melting point) contributes to create a favorable material where compressive stresses are expressed as ridges. Therefore, fluidized crater occurrence can provide a clue for determining what areas should have been ridged if subjected to compressive stresses. Conversely, the overall distribution of ridges may reflect surface properties in addition to the existence of stresses in the crust.

Fluidized crater occurrence

Fluidized craters on Mars exhibit a peculiar surrounding ejecta facies (fig. 1) whose origin has been attributed to ejecta fluidization by subsurface volatiles within the target material (Mouginis-Mark, 1979). These craters were formed at relatively recent times when the meteoritic flux was about constant, and are generally younger than the ridges. There is no obvious latitude control of the different fluidized crater types distribution, with the exception of the pancake craters, which become much more numerous poleward of ±40°. Pancake craters, with a much larger (3 to 6) ejecta range than the other fluidized crater types, indicate that volatile content was higher on the fractured terrains and smooth plains close to the poles, at the time they were formed.

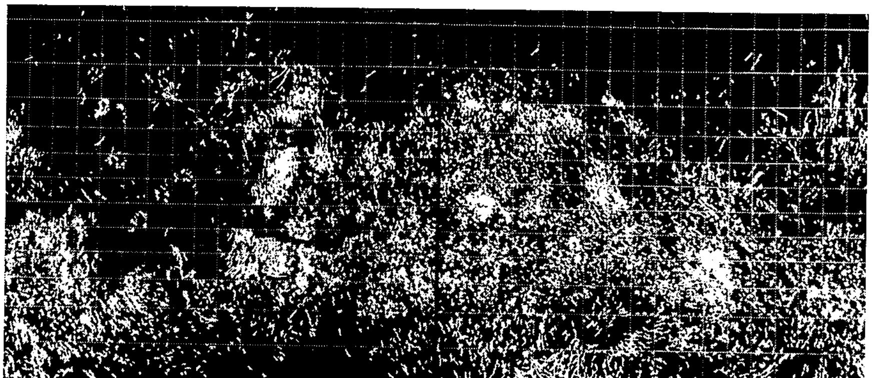

Fig. 2.—Computer-based Martian ridge distribution map, between latitudes of ±65°.

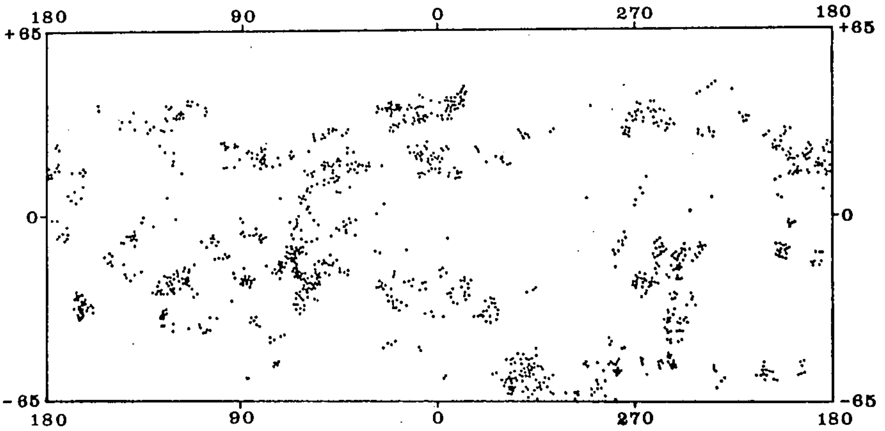

Fig. 3.—Martian fluidized crater distribution map, between latitudes of ±65° (revised from Mouginis-Mark, 1979).

Crater morphology analysis provides some clues about the physical properties of the target material. Central peaks and secondary craters are much more common on Tharsis young lavas than on cratered plains, ridged plains and ancient terrains, in decreasing order, for an average size fluidized crater of 15 km in diameter (Mouginis-Mark, 1979).

Concluding remarks

A comparison of ridge and fluidized crater distribution maps (fig. 2 and 3) shows that all high ridge density areas are also high fluidized crater density areas. Ridge length seems to be controlled by the duration of the low viscosity state (Thomas *et al.*, 1986), which also controls the density of fluidized craters. Therefore, important ridge formation episodes did not exist without a long viscosity state. Compressive stresses induce ridge formation in areas and at times of low viscosity, and do not generate any ridge-like structure in places and at periods of high viscosity.

Acknowledgments

All the help provided by the Lunar and Planetary Institute, Houston, Texas, during previous stages of this work is gratefully appreciated.

This paper was performed under a post-doctoral research contract from the Ministerio de Educación y Ciencia, Spain.

References

Chicarro, A. F. (1983): *Compressive Structures on Mars,* Ph. D. thesis, University of Paris, France.

Chicarro, A. F. and Schultz, P. H. (1982): *Lunar Planet Sci.,* 13, LPI, Houston, 88-89.

Chicarro, A. F. and Schultz, P. H. (1984): *Lunar Planet Sci.,* 15, LPI, Houston, 146-147.

Chicarro, A. F.; Schultz, P. H. and Masson, P. (1985): *Icarus,* 63, 153-174.

Gifford, A. W. (1981): *Ridge Systems on Mars,* Master's thesis, George Washington University, Wash. D. C., USA.

Maxwell, T. A. (1982): *J. Geophys. Res.,* 87, A97-A108.

Mouginis-Mark, P. (1979): *J. Geophys. Res.,* 84, 8011-8022.

Phillips, R. J. and Lambeck, K. (1980): *Rev. Geophys. Space Phys.,* 18, 27-76.

Schultz, P. H.; Schultz, R. A. and Rogers, J. (1982): *J. Geophys. Res.,* 87, 9803-9820.

Thomas, P. and Masson, P. (1986): *Earth Moon Planets,* 34, 169-176.

Recibido el 10 de febrero de 1987
Aceptado el 17 de febrero de 1987

Calderas volcánicas pasivas: un ejemplo en el Estefaniense del Pirineo Catalán

J. Martí. Instituto Jaime Almera. Marti i Franques, s/n. 08028 Barcelona. CSIC. Barcelona.
J. Mitjavila. Departament de Geoquímica, Petrología i Prospecció Geológica. Gran Vía, 585. 08007 Barcelona.

ABSTRACT

A model of volcanic cauldron (pasive volcanic cauldrons) is proposed for some Late-Hercynian basins of the Catalan Pyrenees. This volcanic structure is defined as a sedimentary basin in which the subsidence processes are accelerated by the volcanic activity triggered by the same tectonic processes which are responsible for the basin formation.

Martí, J. y Mitjavila, J. (1987): Calderas volcánicas pasivas: un ejemplo en el Estefaniense del Pirineo Catalán. *Geogaceta,* 2, 19-22.

Key words: *Cauldron, ignimbrites, Stephanian, Pyrenees.*

Introducción

El volcanismo tardihercínico del Pirineo Catalán (fig. 1) está representado por dos ciclos volcánicos (Gisbert, 1981; Marti, 1986). El ciclo más importante, que se desarrolló durante el Estefaniense medio hasta el inicio del Pérmico superior es de naturaleza calcoalcalina, posee un marcado carácter explosivo y está relacionado con un régimen tectónico