CONTRIBUTION TO THE STRUCTURAL INTERPRETATION OF THE VALLES MARINERIS–NOCTIS LABYRINTHUS–CLARITAS FOSSAE REGIONS OF MARS

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Abstract. An inventory of tectonic trends observed in the MC 17 (Phoenicis Lacus) and MC 18 (Coprates) Mars quadrangles, has been constructed on the basis of Mariner 9 and Viking Orbiter images, with regard to their structural significance within the martian history. A scenario for the principal periods and their mechanisms, is proposed with regard to the uplift of the Tharsis Montes–Syria Planum dome.

The Valles Marineris–Noctis Labyrinthus–Claritas Fossae system is one of the most dramatic geomorphic features of Mars. This system is roughly located in the western equatorial region of the planet nearby the Tharsis Montes volcanic range. This area has been intensively covered by Mariner 9 (1971–1972) and Viking Orbiter (1976–1977) images (Blasius *et al.*, 1977).

The importance of the structural significance of this system to a general understanding of Mars tectonic history has been clearly demonstrated by several authors: McCauley *et al.* (1972), McCauley (1979), Masursky (1973), Masursky *et al.* (1978), Carr *et al.* (1973), Carr (1974), Masson (1977), Blasius and Cutts (1976), and Blasius *et al.* (1977). A preliminary study of the structural pattern of Noctis Labyrinthus–Valles Marineris regions, based on Mariner 9 A and B frames, allowed us to set up a first kinematic sketch of the Martian tectonic history (Masson, 1977).

More recent studies of Claritas Fossae (Masson, 1978) and of Noctis Labyrinthus (Masson, 1979), based on Mariner 9 and Viking Orbiter coverages, have contributed to the structural interpretation of this complex system. This contribution aims to correlate these several studies and to submit a general interpretation for the origin of the Valles Marineris – Noctis Labyrinthus – Claritas Fossae system.

1. Physiographic Settings

Valles Marineris, Noctis Labyrinthus and Claritas Fossae are respectively located in the eastern flank, the central part, and the southwestern flank of the Syria Planum–Tharsis Montes uplifted zone (11 km high) (Figure 1).

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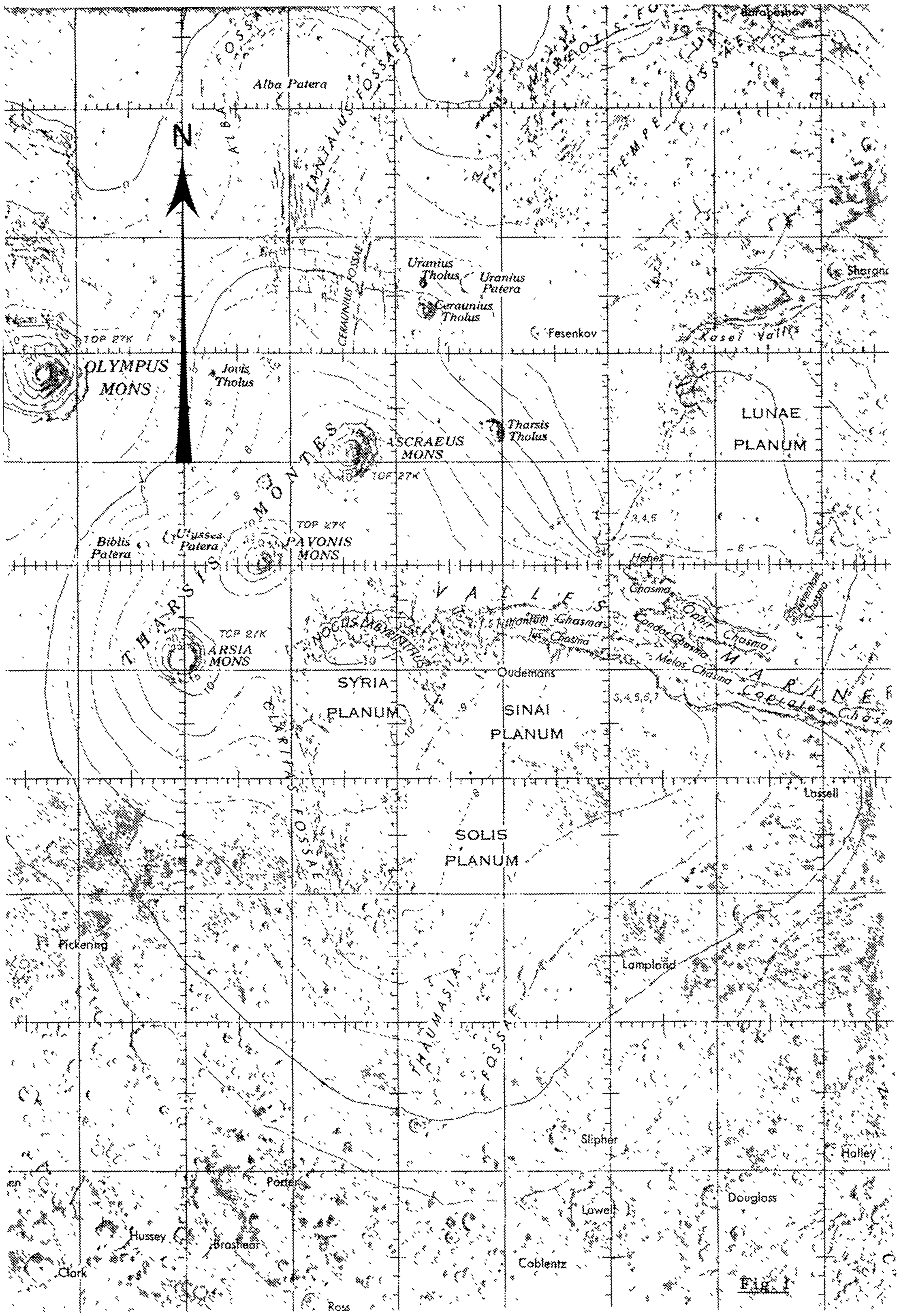


Fig. 1. Location map of Mars (scale 1 : 25 000 000 – contour interval 1 km).

1.1. Valles Marineris

Valles Marineris morphology has been described in detail by Masursky (1973), McCauley (1979) and Blasius *et al.* (1977). According to Blasius Valles Marineris is an enormous canyon system spanning more than one quarter of the equatorial girth of Mars. It exhibits in its landforms the consequences of uniquely Martian extensional tectonics and a variety of erosional and depositional processes. Tectonic control appears to be the fundamental influence on canyon form and evolution, but the style or intensity of tectonism appears to be regionally variable. According to our observations (Masson, 1977) in the Coprates quadrangle (Valles Marineris and vicinity), three distinctive groups of tectonic trends were recognized.

(1) Along Valles Marineris itself (Ius, Melas, Coprates, Eos, Candor and Capri Chasmas), the predominant trend is WNW/ESE, with subordinate trends as follows:

(a) ENE/WSW in Ius Chasma, corresponding to an older pattern in the south rim of the canyon,

(b) NNW/SSE in Candor Chasma as seen in the connection between Candor and Melas Chasmas,

(c) ENE/WSW and N/S in Capri and Eos Chasmas where Valles Marineris is widening to the north and to the south.

(2) To the west and the southwest of the inferred quadrangle (Sinai Planum, Solis Dorsa, and Melas Dorsa), the pattern of the lunar mare-like ridges is controlled by one direction NNE/SSW; this pattern is similar to that of the region to the north of the Coprates quadrangle in Lunae Planum (MC 10) where similar ridges are common.

(3) Felis Dorsa area is characterized by two main directions WSW/ENE and NNW/SSE, and these include both ridges and east trending zone of en échelon fractures.

These several directions of structural trends were correlated with the stratigraphic units defined by McCauley (1979). The WSW/ENE direction is best exemplified in the troughed and furrowed terrains and also in the old cratered terrains. In the recent units this direction is still present but overshadowed by the other trends. The WNW/ESE direction appears in the cratered plains and is also well developed in the canyon floor materials where the lineaments are coincident with the contact between the two types of canyon fill mapped by McCauley. The two youngest units show strong NNW/SSE trends which are present but not strong in the cratered plains unit. The cratered plains on the other hand seem to show in a structural sense a transition between the older structural pattern and the newer pattern of the recent units.

According to these observations the following tectonic chronology is proposed.

(1) The earliest regional tectonic events are seen in the SSW/NNE trends and their WSW/ENE subordinates (they are contemporaneous). These tectonic movements are related to a period of crustal extension which originated Valles Marineris formation.

(2) Then, the major tectonic event occurred: the widening of Valles Marineris along WNW/ESE trends. It is clear (McCauley *et al.*, 1972; Lucchitta, 1974; Blasius *et al.*, 1977) that the present walls and the floor of the canyon have been extensively modified by erosion. There is however, a tectonic pattern that controls this erosional pattern that is

present only in the vicinity of the canyon itself. The directional coincidence of the walls of the canyon, the numerous small parallel graben, and the latter chain craters suggest that a common stress field is responsible for all these features. During the major tectonic period new N/S extensional fractures appeared while the old NNE/SSW and WSW/ENE trends were rejuvenated.

1.2. Noctis Labyrinthus (Figure 2)

Noctis Labyrinthus located at the western end of Valles Marineris, displays a large network of graben looking like valleys. This network is controlled by fault trends mainly oriented NNE/SSW, ENE/WSW and WNW/ESE. These trends are expressed in the old stratigraphic units observed in Noctis Labyrinthus vicinity (pf1 of the inferred geologic quadrangle, Masursky *et al.*, 1978). Polar diagrams of these trends resemble similar diagrams of fault systems over terrestrial domes (Halbouty and Hardin, 1954) and experimentally produced faults over uplifts (Cloos and Cloos, 1934). The walls of these grabens are freshly eroded and they show a large display of landslide features. Their floors are overlaid by slumped materials (collapsed boulders, landslide debris, mudflow looking like deposits) mapped as slope and bedrock materials (sb unit of the inferred geologic quadrange, Masursky *et al.*, 1978). These materials do not show any evidence of erosional activity (fluvial or aeolian). These slumps could be due to a slow creep of surface materials related to freeze-thaw of ground ice, as described in other parts of the planet (Carr and Schaber, 1977). This process would have enlarged and widened these grabens along the old tectonic trends.

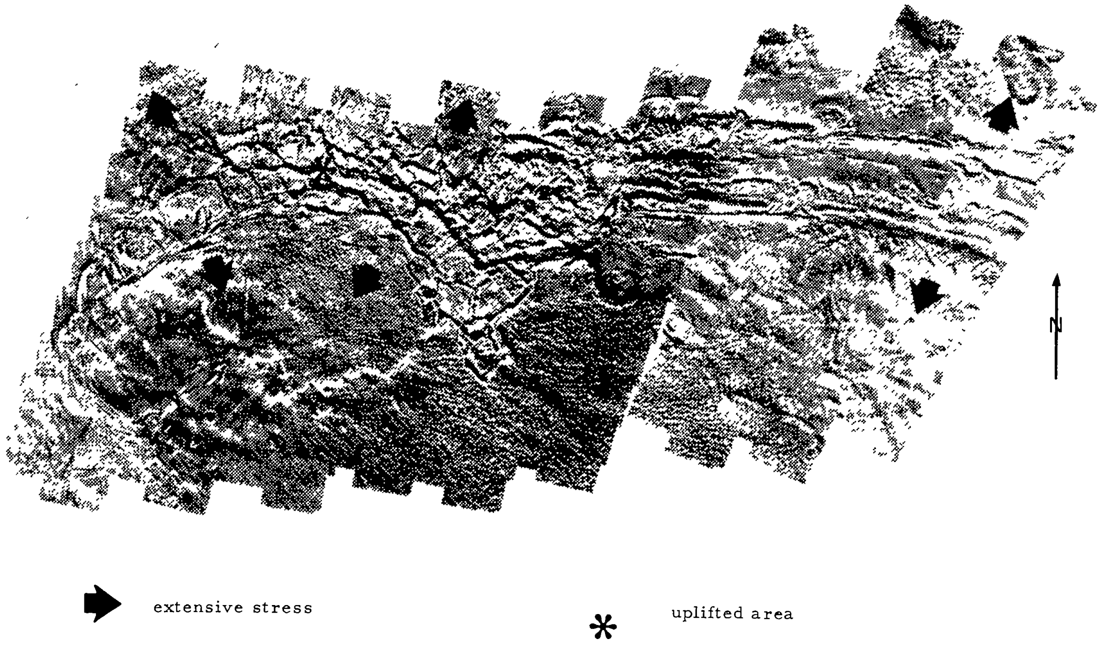


Fig. 2. Viking photomosaic (JPL 211-5271) of the Noctis Labyrinthus–Valles Marineris area of Mars (approx. scale 1:12 500 000).

1.3. CLARITAS FOSSAE: (FIGURE 3)

Noctis Labyrinthus extends westward and southward within the highly faulted and fractured Claritas Fossae system. This system can be divided into three main geomorphic units (Masson, 1978a):

– the northern 'curvature',
– the central 'sigmoidal' zone,
– the southern 'en échelon' faulted zone.

In the northern curvature a system of parallel grabens extends regularly from the Noctis Labyrinthus area (north) to the sigmoidal zone (south). This system seems to continue through the central sigmoidal zone where it is intersected by another major system of grabens extending east–westward. These two units (curvature and sigmoidal zone) are separated by a large dextral strike-slip fault oriented NNW/SSE.

The curvature unit outlines the Syria Planum circular area. In the central (sigmoidal) and southern (en échelon) zones, three main groups of trends are observed:

– N/S trends mainly expressed in the southern part of Claritas Fossae where dextral strike-slip faults are seen,

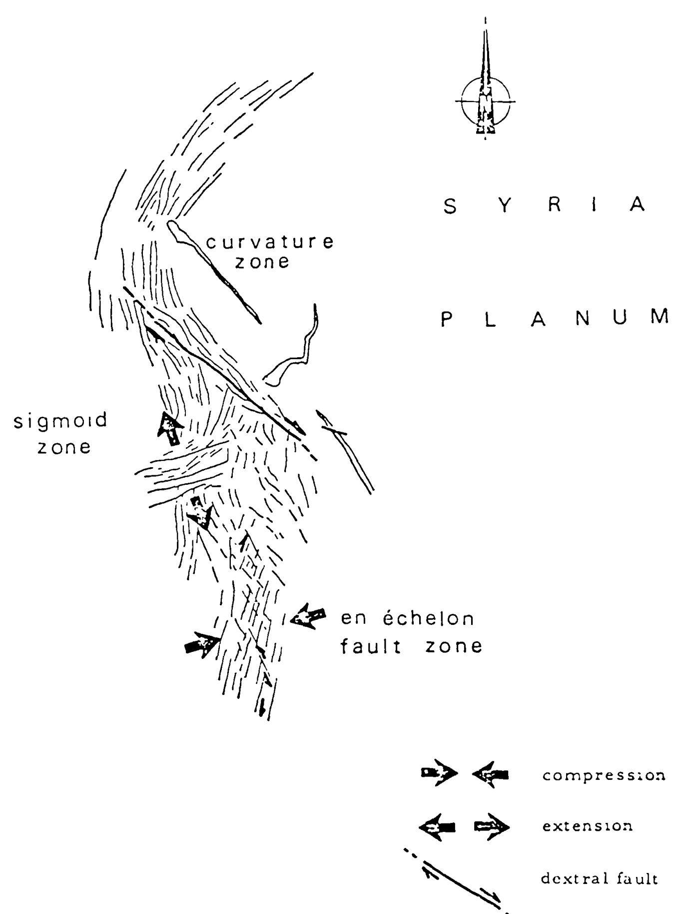
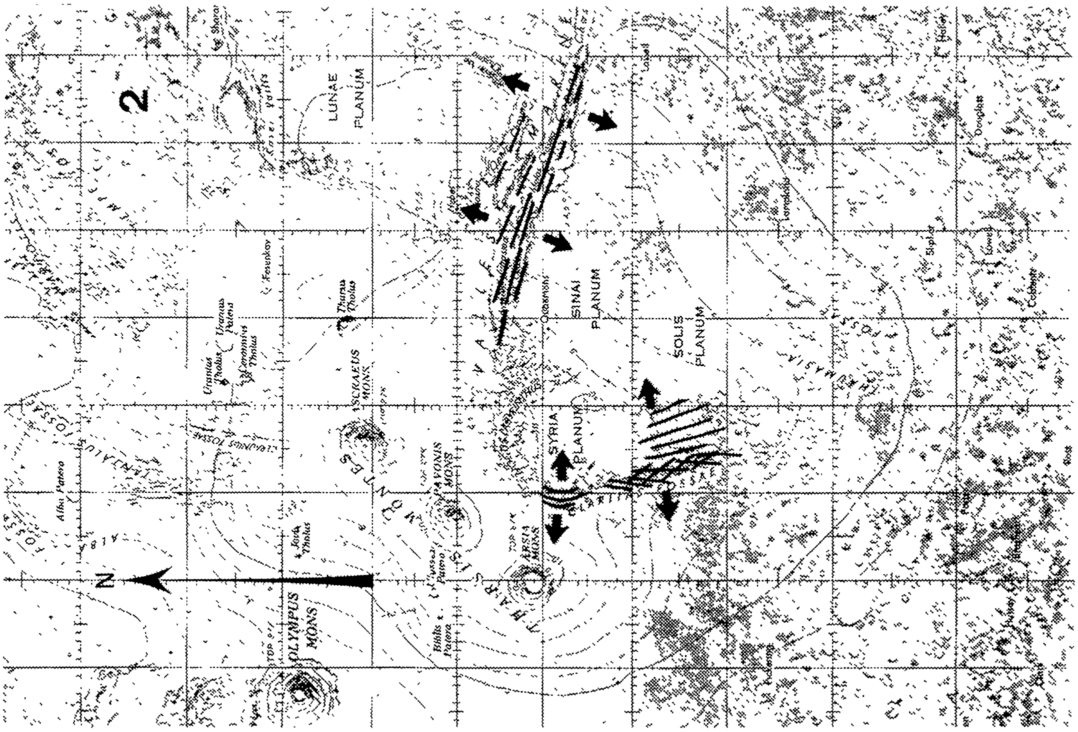


Fig. 3. Detailed structural sketch map of the Claritas Fossae Sigmoid Zone (scale 1:5 000 000).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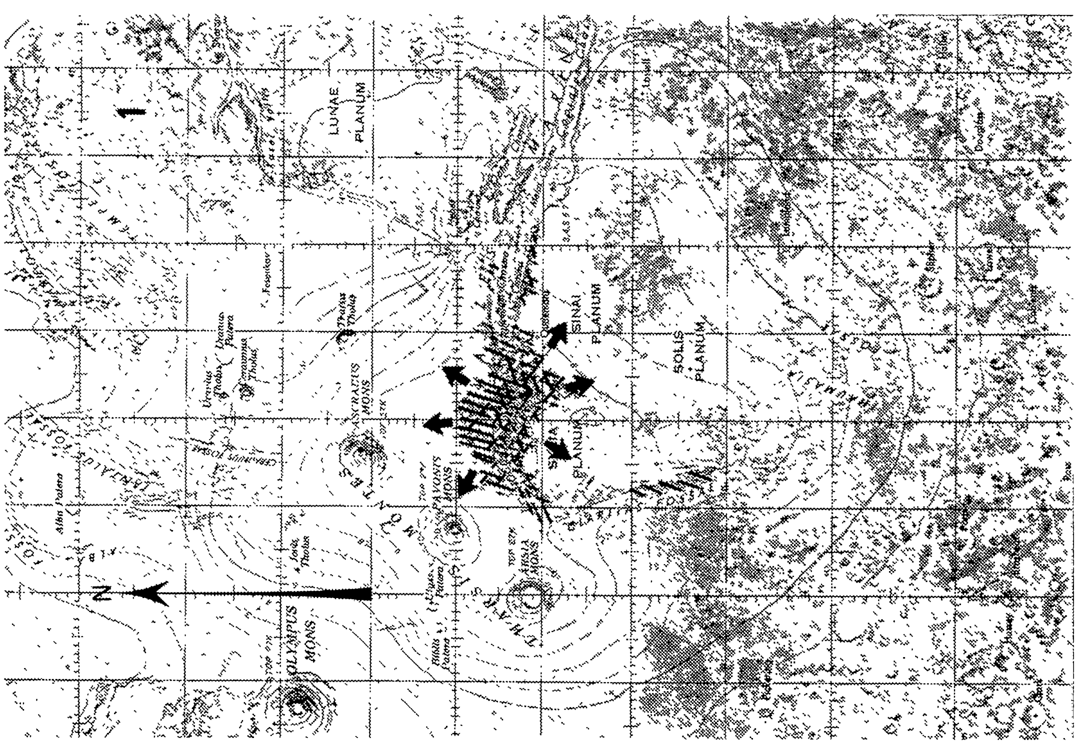
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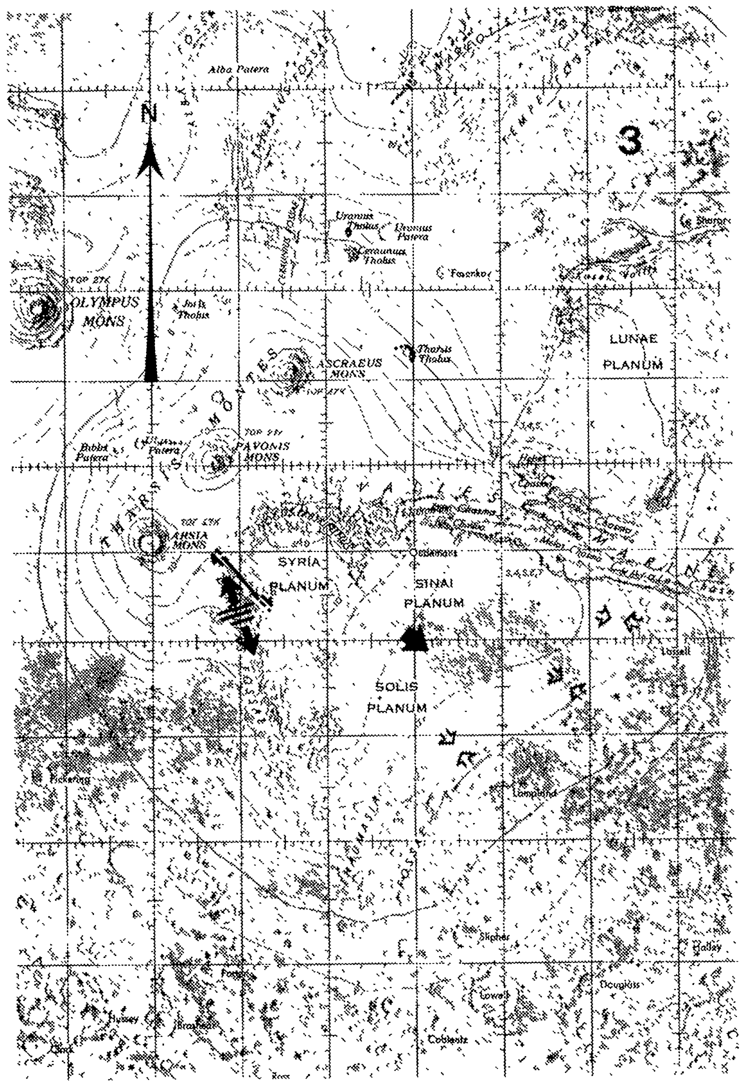

Fig. 4. Sketch maps showing the kinematic scenario of the three main tectonic episodes and of their principal inferred structures (numbers indicate the tectonic episodes).

- main tectonic trends
- dextral strike-slip fault
- extensive movement
- general displacement
- ⇒ ⇐ compressive movement (lobate scarps)

approximate scale = 1 : 100 000 000

– NNW/SSE structures which are the southern extension of the system surrounding Syria Planum. They show some horizontal displacements (sinistral).

– E/W grabens intersecting the two other groups of the above described structures.

These three structural groups seem to be the consequence of several tectonic episodes. The N/S trends could be due to a first stage of extensional movements which involved the entire area of Syria Planum–Noctis Labyrinthus–Claritas Fossae during the first period of a general updoming episode. The major updoming period produced the curvature and its southern extension (NNW/SSE structures), i.e., the widespread system of faults and grabens observed in the central and southern parts of Claritas Fossae.

2. General Conclusions

This overview of the several tectonic movements which occurred in Valles Marineris, Noctis Labyrinthus, and Claritas Fossae leads us to the following kinematic scenario (Figure 4).

During a first tectonic period (possibly related to the early stages of the Tharsis Montes–Syria Planum uplifting), a primitive structural pattern of tensional fractures was created. This pattern in the northern part of Valles Marineris and its rims, as well as in the Noctis Labyrinthus area, (Figure 4(a)).

A second period related to the major uplifting episode would have initiated the Valles Marineris opening movements and the grabens formation in the Labyrinthus Noctis–Claritas Fossae areas (Figure 4(b)).

The paroxismal period of updoming would have consequently produced the late lateral extending movements of Valles Marineris, the general deformation of the sigmoidal zone and the formation of E/W grabens in Claritas Fossae. Some compressive movements observed in the south of Claritas Fossae could be due to extensive movements occuring in the Valles Marineris area. These compressive deformations would have been contemporaneous of NNW/SSE thrusting and of a general displacement toward the south-east along the Claritas Fossae en échelon fault zone (Figure 4(c)).

During the last steps of the Tharsis Montes–Syria Planum uplifting, an increase of the heat flow would have occurred in the Syria Planum–Noctis Labyrinthus area. This geothermal activity was probably related to the volcanic activity of the Tharsis Montes. This phenomena could have melted the ground ice along the structural trends observed in the Noctis Labyrinthus area where the updoming deformation seems to be the most intensively expressed. Due to this freeze–thaw of ground ice wall materials collapsed and grabens widened by creeping and slumping processes.

Although we do not know precisely the general significance of these structural mechanisms (with regard to the internal evolution of the martian crust), the Valles Marineris–Noctis Labyrinthus–Claritas Fossae are of Mars appears to be resulting of tectonic and geothermal (at least for Noctis Labyrinthus) activities which have the same origin, i.e., Tharsis Montes–Syria Planum updoming movement which extended during a large period of the planet history (Wise, 1978) until a very 'recent' period of time (Masson, 1978b).

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