acta geologica polonica

Vol. 23, No. 2 Warszawa 1973

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Tectonic lineaments in Northern Libya

ABSTRACT: Described are linear structures readable on aerial photographs in form of dark strips, running approximately at azimuth 150° in the prolongation of the Giofra Graben in Northern Libya. Dark tint of the strips is caused by desert varnish. On the surface of the land the structures consist of large, up to 5 m blocks of the Had Limestone Member cemented with carbonate crusts. Both blocks and crusts are cut by fine veinlets of limestone mylonites. The lineaments developed in result of oscillation movements of deep faults connected with geotectonic development of the Sirte Basin which was probably influenced by the results of tides of the Earth crust.

INTRODUCTION

A group of lineaments occurs in the northwestern prolongation of the Giofra Graben between Wadi Sofeggin and Wadi Zemzem in Northern Libya. Paleogene yellowish limestones and dolomites of the Had Limestone Member expose on the surface in the area in question (*cf.* Jordi & Lonfat 1963). These are thick bedded (20—50 metres) erosion resistant rocks forming a distinct vast plateau. Only in few sites they are covered with remnants of limestone and marls of the Surfa Formation (Figs 1 and 3).

Acknowledgements. The author is grateful to Docent A. Radwański for a critical reading of the manuscript and helpful discussion.

SETTING AND STRUCTURE OF THE LINEAMENTS

Dark strips are observable on aerial photographs of the investigated area (*cf.* Ostaficzuk 1973) running along straight lines of direction 150°, and varying in width (Fig. 2). Dark tint of the strips is caused by the presence of desert varnish which developed mainly in sites of these lineaments. The lineaments are spaced, one per some kilometres, up to several per one kilometre, and their length varies from 30 to 80 kilometres within the investigated area. The axes of the lineaments which are covered with desert varnish are elevated approximately 0.5—2.0 metres above the surrounding surface and are several tens of metres broad (Figs 4—5).

The lineaments consist of coarse breccia built of blocks of the Had Limestone Member. The blocks are 0.5 up to 5 m in diameter, and are cemented, under subaerial conditions, by carbonate crusts, yellowish to brownish in color, surrounding the blocks concentrically. Both incrustations and blocks are cut by thin, pinkish veinlets of mylonitized cal-

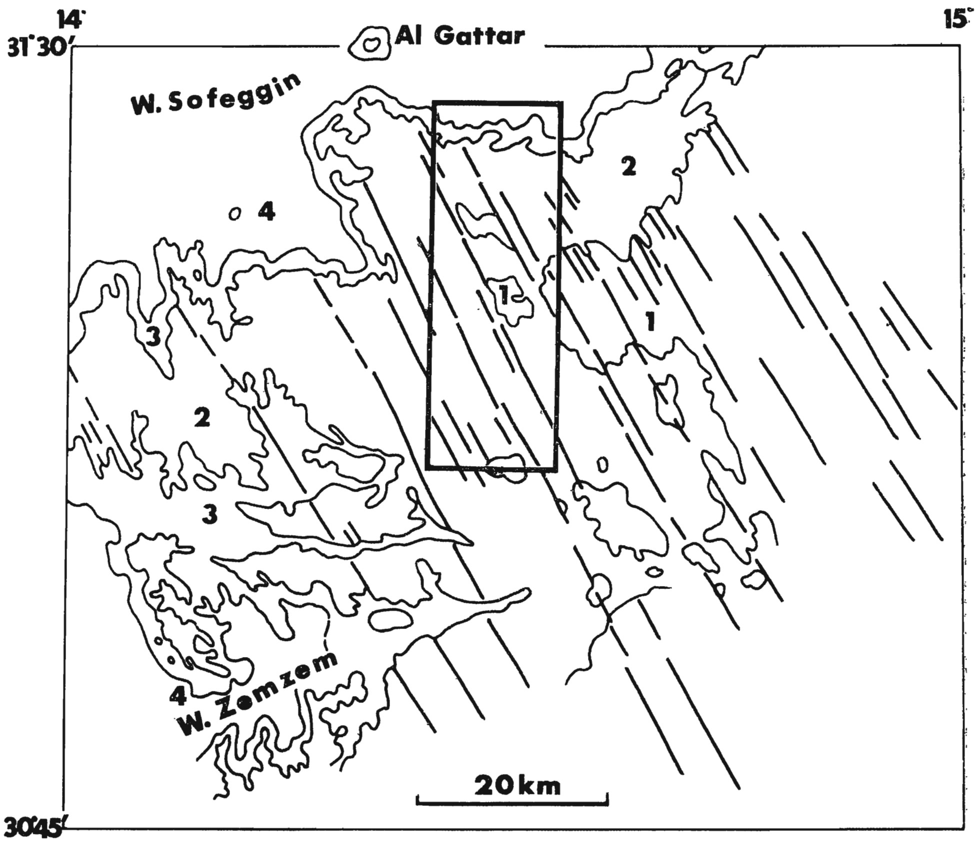

Fig. 1

Photogeological map of the Al Gattar and Wadi Sofeggin area in north-western Libya (*cf.* Fig. 3)

1 marls of the Surfa Formation (Paleogene), *2* Had Limestone Member (Paleogene), *3* Upper Tar Marl (uppermost Cretaceous-Paleogene), *4* Upper Cretaceous marls and limestones
Dash-lined are the distinctive lineaments; rectangled is the area of Fig. 2

Air photographs of the investigated area presenting lineaments in the south of Wadi Sofeggin (*cf.* Fig. 1). Top part of figure comprises the large-scale-landslide area (*cf.* Ostaficzuk 1973), bottom part of figure spotted in black by shadow of clouds. Circled is a part of the lineament presented in Fig. 4

Courtesy of *Aminoil International Co.*

cium carbonate which proves the existence of tectonic movements younger than the precesses of the cementation of breccia. The particular blocks form rather regular rhomboidal pattern; longer diagonals of the rhombs are parallel to the lineaments (Figs 5—6) which corresponds to the joint-fault pattern of a tensional origin (*cf.* De Sitter 1964).

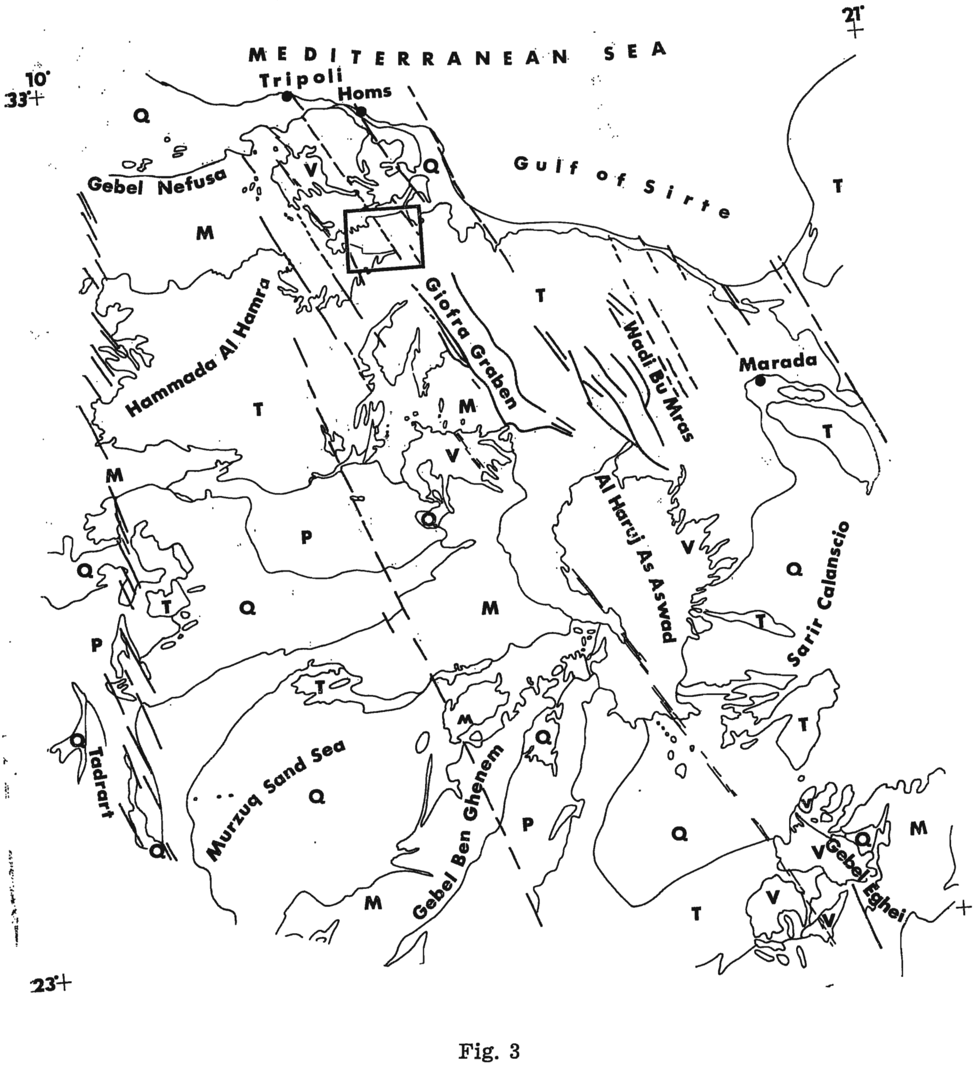

Fig. 3

Geological map of north-western Libya (after Conant & Goudarzi, 1964; modified)
Q Late Tertiary and Quaternary deposits, *T* Tertiary formations, *M* Mesozoic formations, *P* Basement Complex and Paleozoic formations, *V* volcanic rocks (Tertiary and Quaternary); rectangled is the area of Fig. 1

Fig. 4

A distanctive lineament *c.* 50 m wide; for localization — see Fig. 2

ORIGIN OF THE LINEAMENTS

Subaerial origin of the discussed zones of fractures on the surface, or only under thin cover of the Surfa Formation, small spaces inbetween the zones as compared to their length, and lack of evident displacements of a fault character, prove that the fractures could not originate in one tectonic act. The lineaments may therefore be regarded as a result of some tectonic discontinuities of the deeper substrate (*cf.* Pesce 1968). Narrow, parallel lineaments were formed as fatigue structures (*sensu* Kendall & Briggs 1933, *fide* Price 1966) in result of multiphase bending of the substrate along an axis parallel to the developing linear discontinuities. The bending may be explained by action of sinusoidal vertical movements (*sensu* Sanford 1959) in the substrate of the Basement Complex. Taking into account the existence of deep fractures in the Basement Complex, gentle vertical movements change into displacements of the fault type along the surfaces of the fractures. The faults cease in the sedimentary cover passing into flexures and gentle folds. Tension and compression zones appear from time to time within the folds which are concordant with the state of the fault in the substrate. In the rigid cover of the Had Limestone Member, gentle bendings shifting to the left or right, and depending

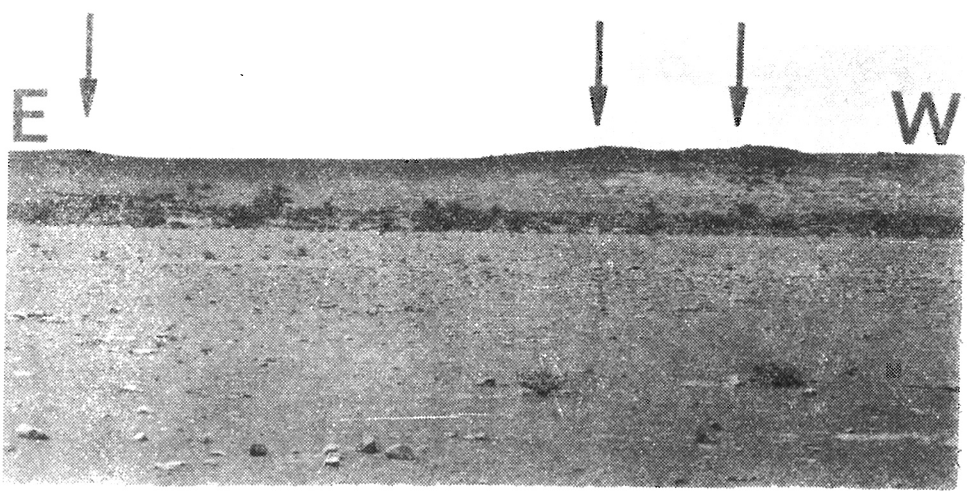

Fig. 5

Distinctive lineaments resulting in elongated breccia-and-crust zones with dark desert varnish, being erosionally cut by a wadi escarpment

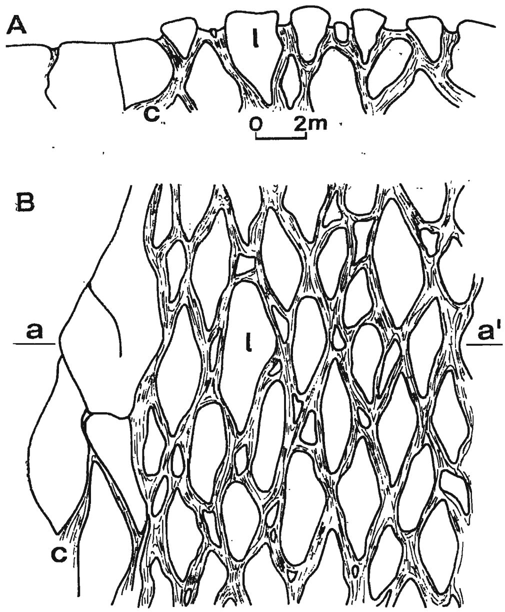

Fig. 6

Breccia pattern in a lineament
A cross section along *a—a'* line in Fig. *B* presenting vertical view
l blocks of the Had Limestone Member, *c* limestone crust

of which flank of the deep fault was uplifted, cause the formation of zones of crackings near the surface (Fig. 7).

Opening and tighting of fissures is connected with the process of the oscillational recurrence of tension and compression. Squeezing of softer rocks into the fissures takes place during the opening of cracks, as well as shooting of weathering debris and crystallization mainly of calcium carbonate, precipitated from the solutions. When tighting of the fissures takes place, in result of an increasing compression, the rock material is squeezed, which in the case of lack of the overburden leads to pressing it upwards. Small displacements and shears appear within the calcium carbonate crusts, which is proved by the existence of mylonites. During tension, the beds do not come back to their primary state but remain partly disturbed and the cracks become recurrently opened.

The causes of the oscillation movements in the wings of the fractures in the substrate are supposedly connected with the geotectonic processes modelling the neighborhood of the Sirte Basin. The existence of deep fractures in the substrate of the area in question is supported by the lines several hundreds of kilometres long which are descernible on space photographs and are of a great importance in regional geology of Libya (Fig. 3). Many geological structures delineate a line of azimuth 150° running from Tripoli and Homs toward the Giofra Graben and farther to Al Haruj al Aswad and Gebel Eghei; these are the tectonic grabens, faults, border limits of Mesozoic sediments on the surface, sites of volcanic activity. Earthquakes are also known to occur in historical (Haynes 1965) and recent times (Gorshkov 1963) along this line, of at least 7° in Richter's scale. Periodical displacements of the margins of the deep fracture Tripoli — Gebel Eghei are a result of summing up of horizontal movements of both western and eastern margins of the Sirte Basin. The latter led to subsidence and development of the Sirte Basin with simultaneous isostatic compensation in its wings (Fig. 8). Despite of several transgressions and regressions in the Sirte Basin, a general tendency to subsidence in the central part of the basin is to be noted there beginning from the Late Cretaceous time. Taking into account a time span from the beginning of the Cenozoic to recent times this subsidence is estimated as several thousands of metres (Hecht & al. 1964, Conant & Goudarzi 1967). The author's investigations revealed that from the Middle Miocene time the uplift of the border wings of the basin in regard to its axial part may be estimated as over 200 metres, which is proved by the position of the littoral sediments of the Middle Miocene sea. Near Marada these sediments rest at about 70 metres a.s.l. and several tens of kilometres to the west they are situated at an altitude of over 300 metres, near Wadi Bu Mras. The bending of the margins of the Sirte Basin increased with the

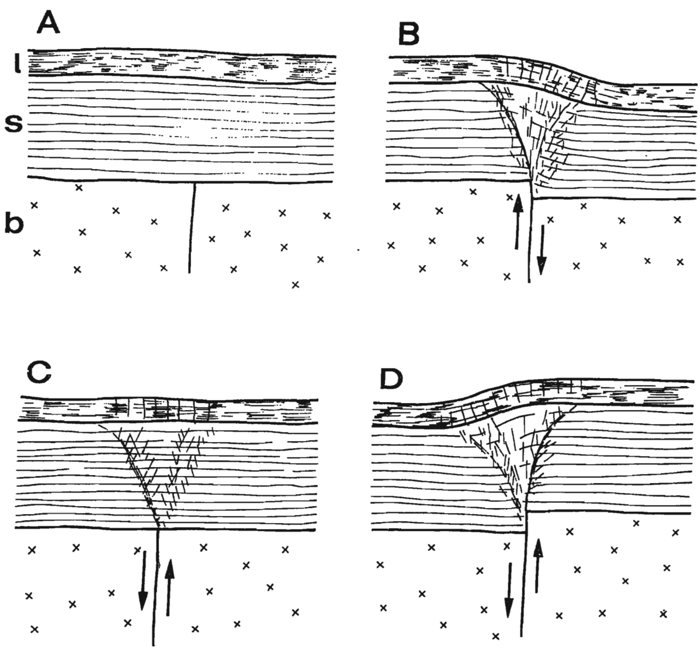

Fig. 7

Successive stages (*A—D*) of development of the crash zone above a deep-seated fault

b Basement Complex, *s* sedimentary rocks, *l* Had Limestone Member (capping bed) subsidence of its axial parts thus being conducive to the origin of vertical faults, the uplifted wings of which being situated outward the basin axis. Thus the discussed deep-seated faults may be regarded as a transfor-

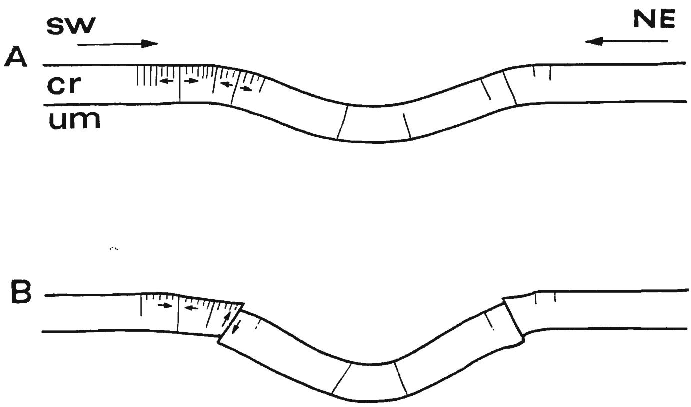

Fig. 8

Sketch of a supposed development of the Sirte Basin and origin of the deep-seated faults

A primary phase: fault stress increases and results in the opening of fissures, *B* fault phase: compression of fissures
um Earth's upper mantle, *cr* Earth's crust

mation of slow subsidence into periodical, rapid vertical displacements along the existing or newly developed dislocation lines. The bending of the platform margins toward the basin axis must be accompanied by slight opening of all fractures parallel to the bending axis. After the tension is released by faults a subsequent closing of fissures takes place in the uplifted wing. Tides of the Earth crust might have been an additional factor influencing the sinusoidal movements of the basement and activation of faults (*cf.* Okhocimskaya 1967). The African Shield is comparable in its dimensions to the tide swell (Garland 1965) thus each advance of the tide wave is accompanied by tensions (Blanchet 1957), which must accumulate near tectonic discontinuities of the basement. Over such discontinuity of the substrate, elastic bendings should be replaced by hinging of wings which may be compared to the rims of icefloe tightly covering the surface of waving water (Fig. 9). The tide tensions may accumulate with those of tectonic nature and lead to more frequent faulting than it might result only from the development of large-scale geotectonic processes. Thus successive, repeated displacements of small amplitude signalled by moderate earthquakes are more probable than large ones of catastrophic character. This may lead to the development of many parallel lineaments in the uplifted wing of a deep-seated fault.

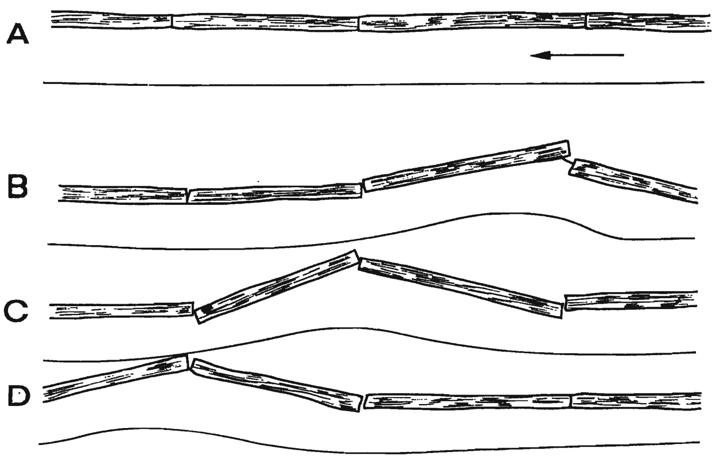

Fig. 9

Motion of icefloe on a waving water surface (marked is a single wave only; continuous line marks a wave amplitude)

AGE OF THE LINEAMENTS

The great fractures are most probably of Paleozoic age as they control the differentiation of Mesozoic facies. The lineaments in their actual form might have been formed after the plateau was developed, *i.e.* after the Miocene (Desio 1953). The presence of mylonites and their shear in weathering carbonate crusts within the lineaments proves the tectonic processes being active in these zones till the Recent times.

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GENEZA LINEAMENTÓW TEKTONICZNYCH PÓŁNOCNEJ LIBII

(Streszczenie)

Przedmiotem pracy jest analiza linearnych struktur tektonicznych uwidaczniających się na zdjęciach lotniczych w postaci ciemnych smug, a rozciągających się w azymucie *ok.* 150° na przedłużeniu rowu tektonicznego Giofra w północnej Libii (*por.* fig. 1—3).

Rozważane struktury, zaznaczające się na powierzchni terenu nagromadzeniem wielkich (do 5 m średnicy) bloków paleogeńskich wapieni formacji *Had Limestone,* spojonych naciekami węglanowymi i pokrytych ciemnymi polewami pustynnymi (*por.* fig. 4—6), są lineamentami tektonicznymi. Zarówno bloki, jak i nacieki pocięte są drobniejszymi żyłami mylonitów wapiennych.

Genezę lineamentów autor wiąże z oscylacyjnymi przemieszczeniami skorupy ziemskiej zachodzącymi wzdłuż wgłębnych uskoków. Przyczyną takich oscylacyjnych ruchów na badanym obszarze są procesy związane z geotektonicznym rozwojem basenu sedymentacyjnego Syrty, na które zapewne nakładają się także skutki pływów skorupy ziemskiej (*por.* fig. 7—9).

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