THE TECTONIC REGIONING OF THE BASEMENT ROCKS OF THE EASTERN DESERT OF EGYPT

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ABSTRACT

The basement rocks of the Eastern Desert of Egypt represent a Proterozoic eugeosynclinal system. This system is the northern part of a vast geosynclinal belt which extends southwards into the Ethiopean plateau. It is divided into three major geosynclinal zones, namely: *a)* Wadi Allaqi-Wadi Kharit zone, with Gebel Holwa-Gebel Seiga-Gebel Nigrub, and Gebel Migif — Gebel Hafafit median masses in its southern and northern parts, respectively, *b)* Wadi El Miyah — Wadi Atalla geosynclinal zone, which includes Gebel Meatiq median mass, and *c)* Wadi Belih — Wadi Hawashiya geosynclinal zone. These zones are generally bordered by deep-seated faults, and are separated from each other by Gebel Abu Diab and Gebel El Shayeb geoanticlinal zones. The median masses are probably Archean-Lower Proterozoic, and might have existed prior to the Proterozoic eugeosynclinal system.

This tectonic regioning is based on the results of the regional geological mapping programs, field observations of the authors, the distribution and lithology of the different rock formations and their structural relations, as well as the geomorphological features of the area under consideration.

INTRODUCTION

The construction of a tectonic framework, and consequently a tectonic map for an area is an essential step in the preparation for mineral exploration programs. This is evident, since certain groups of mineral and ore deposits are formed under special tectonic conditions or within a specific structural pattern. In addition, tectonic regioning is also of scientific interest where it may help in the study of the development and evolution of the Earth's crust as a whole, or a specific structure within it.

The absence of such a tectonic regioning for the basement rocks of the Eastern Desert of Egypt was the reason behind the non-representation of its structures on the tectonic maps of Egypt presented by SIGAEV [1959], and SIGAEV and SALLOUM [1971].

The present study is a first step in the delineation of the main tectonic features of this area. Such a study, may lead in the future to the construction of a detailed tectonic map for the Eastern Desert.

The general characteristics and relationships of the basement rocks of the Eastern Desert, their geological history, the lithology of the different formations, as well as the wide distribution of magmatism and plutonism may indicate that this area belongs to a geosynclinal system. This system extends for about 800 km in Egypt, and continues southwards into the Sudan. Its width ranges from 260 km in its southern parts to about 10 km at the extreme north. This system is believed to be the northern part of an extensive geosynclinal belt which extends southwards into the Ethiopean plateau.

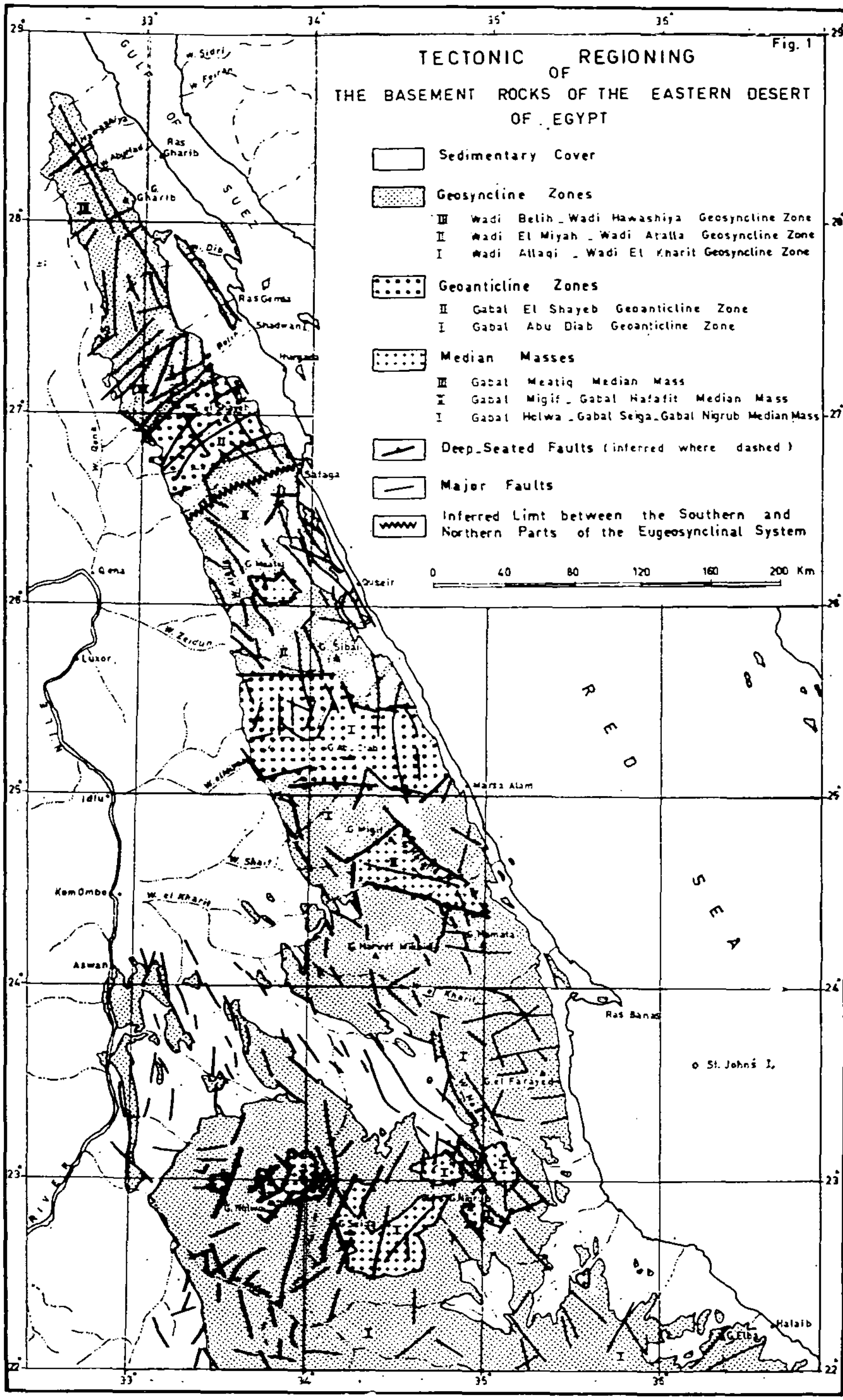
Fig. 1
TECTONIC REGIONING OF THE BASEMENT ROCKS OF THE EASTERN DESERT OF EGYPT
Sedimentary Cover
Geosyncline Zones
III Wadi Belih _ Wadi Hawashiya Geosyncline Zone
II Wadi El Miyah _ Wadi Atalla Geosyncline Zone
I Wadi Allaqi _ Wadi El Kharit Geosyncline Zone
Geoanticline Zones
II Gabal El Shayeb Geoanticline Zone
I Gabal Abu Diab Geoanticline Zone
Median Masses
III Gabal Meatiq Median Mass
II Gabal Migif _ Gabal Hafafit Median Mass
I Gabal Helwa _ Gabal Seiga _ Gabal Nigrub Median Mass
Deep_Seated Faults (inferred where dashed)
Major Faults
Inferred Limt between the Southern and Northern Parts of the Eugeosynclinal System
0 40 80 120 160 200 Km
RED SEA
GULF OF SUEZ
Ras Gharib
Safaga
Quseir
Marsa Alam
Ras Banas
St. Johns I.
Halaib
Qena
Luxor
Idfu
Kom Ombo
Aswan
RIVER NILE

Fig 1

Before going into the tectonic regioning of the basement rocks, it may be useful to give in few words, the concepts of some of the terms used here.

A geosynclinal mobile belt is one of the most important megastructures in the Earth's crust. It is characterized by maximum tectonic activity, and forms the foundation over which other structural types of the continental crust such as the platforms, epiplatforms, geoanticlinal mobile zones and others, may be superimposed. It is always limited on both sides by two old continental platforms or a continental and an oceanic platform. Its development took place during an extensive megacycle and at different ages, moreover some of its parts may pass into platformal conditions. The whole Tythean belt which is bordered by the Russian and African platforms is an example. The geosynclinal belt may include several geosynclinal systems, each of which reaches 1000—3000 km in length and 200—5000 km in width. These geosynclinal systems in their turn, include some comparatively smaller basins and uplifts, referred to as the geosynclinal and geoanticlinal zones, respectively. Primary, or orthogeosynclines were classified by STILLE [1940] into eugeosynclines and miogeosynclines. Both types differ in their evolution, history of development and intensity of magmatic activity. Generally speaking the eugeosynclines are more mobile, better developed and characterized by more intense magmatism or polymagmatism including an initial phase, mainly of basic and ultrabasic volcanism, a synorogenic phase essentially of granitoid plutons and a post-orogenic phase represented mainly by dykes.

Deep-seated faults play an important role in the development of the geosynclinal systems. They are characterized by their great depth of penetration and hence their connection with deep magmatic activities [PEYVE, 1945], their repeated rejuvenation and their surface extension for long distances. Their zones of activity usually range from 1 to 3 km across the strike but may reach up to 5 or 6 km. It is believed that the initiation and further development of any geosynclinal system is genetically connected with the presence of deep-seated faults, along which separate blocks or mozaics of the Earth's crust may move giving rise to the different structural elements of the geosyncline. Moreover, the movement of these blocks is usually governed by major regional structural trands.

THE TECTONIC REGIONING OF THE BASEMENT ROCKS OF THE EASTERN DESERT

The tectonic regioning of the basement rocks is based on the regional geological maps presented mainly by members of the staff of the Geological Survey of Egypt and partly by some other organizations ,as well as some field observations by the authors. The tectonic regioning was facilitated by the compilation of the geological map of the Eastern Desert on the scale of 1:1,000,000 carried out by EL RAMLY [1972]. Admittedly, this tectonic regioning is a generalized one. A better and more detailed picture may be constructed in the future, with the accumulation of more detailed information allowing the exact locations, sizes and degree of complication of the different structural elements involved. Boundaries between the different structural elements along the deep-seated faults are given tentatively. Their original positions are difficult to recognize because of the later intrusion and effusion of huge magmatic bodies. Also, some of them may be concealed below younger sediments. According to MOURATOV [1963], regioning of the Proterozoic geosynclines is based on their main rocks which were formed during the pre-orogenic stage of their deve-

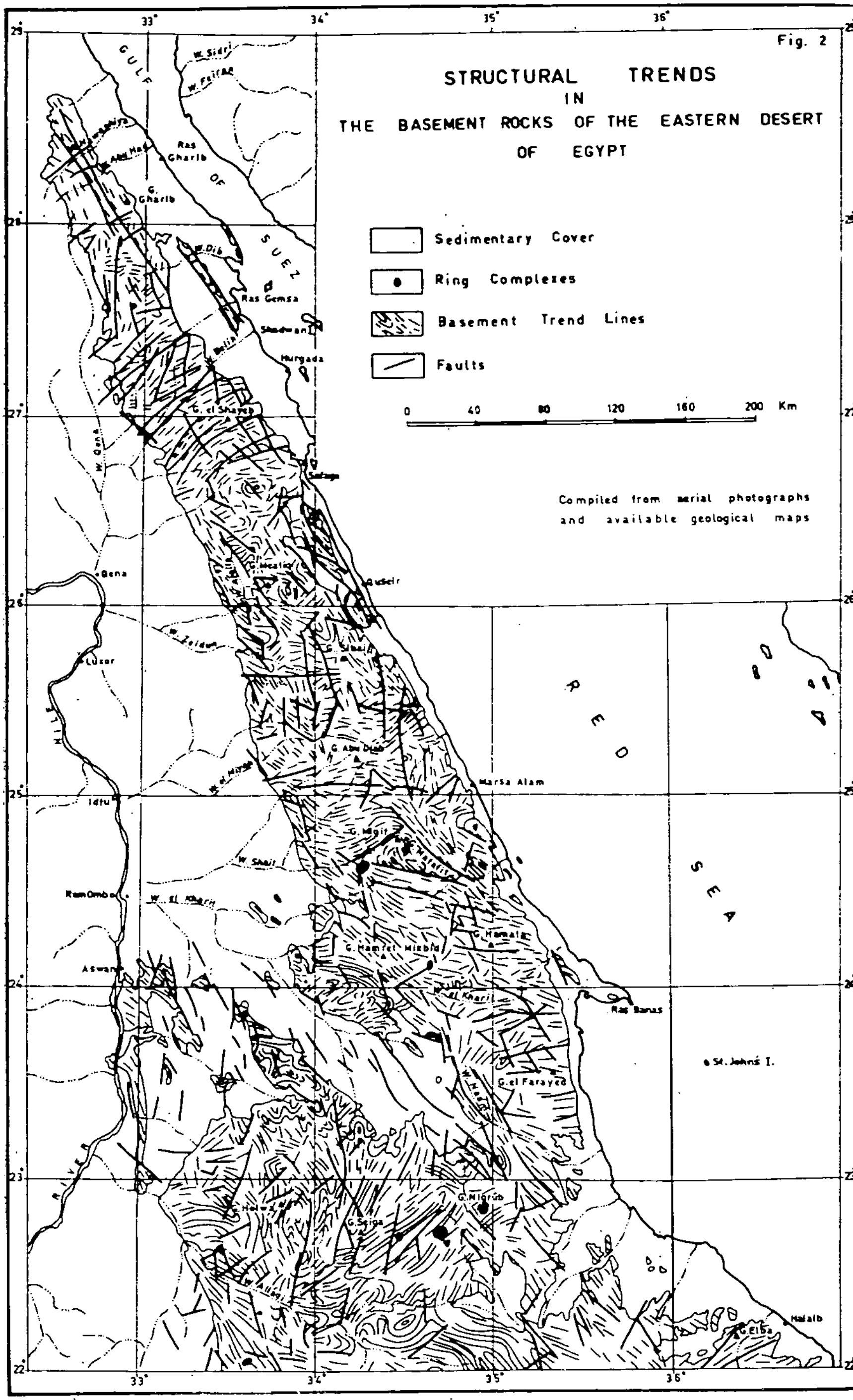
Fig. 2
STRUCTURAL TRENDS
IN
THE BASEMENT ROCKS OF THE EASTERN DESERT
OF EGYPT
Sedimentary Cover
Ring Complexes
Basement Trend Lines
Faults
0 40 80 120 160 200 Km
Compiled from aerial photographs
and available geological maps
GULF OF SUEZ
RED SEA
RIVER NILE
33°
34°
35°
36°
29°
28°
27°
26°
25°
24°
23°
22°
W. Sidri
W. Feiran
Ras Gharib
G. Gharib
W. Dib
Ras Gemsa
Shadwan I.
Hurgada
G. el Shayeb
W. Qena
Safaga
Qena
Quseir
W. Zeidun
Luxor
G. Sibai
G. Abu Diab
W. el Miyah
Marsa Alam
Idfu
G. Migif
W. Shait
Kom Ombo
W. el Kharit
G. Hamata
G. Hamrat Misbid
Aswan
Ras Banas
St. Johns I.
G. el Farayed
G. Nigrub
G. Seiga
W. Allaqi
Halaib
G. Elba

Fig. 2

lopment. In the present case, the complex of rocks formed before the effusion of the Dokhan volcanics were taken as the basis for regioning. The geosynclinal system forming the basement rocks in the Eastern Desert is characterized by:

1) The high mobility of the Earth's crust.
2) The pronounced activity of magmatic intrusions and effusions or its polymagmatism.
3) The predominance of spilitic-keratophyric and prophyritic formations.
4) The original thick sedimentary sequence which at Gebel El Sibai, for example, reaches a thickness of about 7.7 km [Sabet, 1961].
5) The absence of regional unconformities within this sedimentary series.

These characteristic features indicate that, this system conforms with the eugeosyncline or internal zone of the orthogeosyncline as defined by Stille [1940].

The northern part of the eugeosyncline, north of the Latitude 26° 30′ has certain characteristics of its own. These are:

1) The predominance of granite-granodiorite plutons which form about 90% of the exposed basement rocks. These were intruded mainly in the orogenic and post-orogenic stages of the eugeosyncline.
2) In the pre-orogenic stage the magmatic activity was compartively less than that in the internal zone to the south.
3) Basic and ultrabasic intrusions are comparatively rare.

These particular characteristics made it possible to divide the eugeosyncline into two parts, a southern or internal zone and a northern or external zone *(Fig. 1)*. The border-line between these two zones is inferred, and is located just to the north of the Latitude 26° 30′.

Concerning the main structural features of the eugeosyncline as a whole, the following two main points may be noted:

1) The metasediments are generally thrown into fold mainly of the linear Alpine type.
2) Many of the wadis were eroded along fault planes, as indicated by the brecciation of the rocks forming the margins of these wadis.

Fig. 2 shows the major regional structural trends of the eugeosynclinal system of the Eastern Desert, which indicate clearly the mozaic structure of the Earth's crust within this area. These mozaics are separated from each other by deep-seated faults which may extend for considerable distances both along the strike and in depth. The exact locations of these deep-seated faults and the depth to which they penetrate are not known with certainty due to the lack of detailed structural-geophysical data, particularly aeromagnetic, over most of the area. The faults show frequent rejuvenation, in fact some of them may be in a stage of reactivation at present. Their inferred locations are shown on *Fig. 1*.

Based upon the available data, the *Proterozoic eugeosyncline*, can be divided into the following structural units from south to north *(Fig. 1)*.

1) Wadi Allaqi—Wadi Kharit geosynclinal zone which includes Gebel Holwa — Gebel Seiga — Gebel Nigrub median mass in its southern part and Gebel Migif — Gebel Hafafit median mass in its northern part.
2) Gebel Abu Diab geoanticlinal zone.

3) Wadi El Miyah — Wadi Attala geosynclinal zone, which includes Gebel Meatiq median mass.
4) Gebel El Shayeb geoanticlinal zone.
5) Wadi Belih — Wadi Hawashiya geosynclinal zone.

In naming these zones, a geosynclinal zone was named after the main wadis in the corresponding area, whereas a geoanticlinal zone was named after the highest mountain (Gebel) within the zone. Names of the median masses correspond to the main mountains within its limits.

To sum up, the eugeosynclinal system of the Eastern Desert is divided by two comparatively narrow geoanticlinal zones namely Gebel Abu Diab and Gebel El Shayeb into three major geosynclinal zones; Wadi Allaqi — Wadi Kharit, Wadi El Miyah — Wadi Atalla and Wadi Belih— Wadi Hawashiya geosynclinal zones. In addition to these two major structural elements, a third type namely the median masses is also encountered within the geosynclinal zones. These median masses are Gebel Holwa — Gebel Seiqa — Gebel Nigrub, Gebel Migif — Gebel Hafafit and Gebel Meatiq. The main tectonic features of each of these structural elements is given below.

1. Geosynclinal zones

As defined by SHATSKY [1946], geosynclinal zones are simple syncline-like forms which were subjected to a prolonged period of sinking that resulted in the accumulation of very thick bodies of sedimentary and magmatic rocks.

a) Wadi Allaqi — Wadi Kharit geosynclinal zone: This zone extends for about 330 km with a maximum width of 260 km. It represents a trough filled with a thick sedimentary sequence (now metamorphosed into the metasediments), submarine volcanics and volcanic intrusions of varying composition. The major structural trends in this geosynclinal zone are complicated. In the area around Wadi Allaqi, they predominantly follow a roughly NE—SW direction *(Fig. 2)*, whereas in the area south of the Migif — Hafafit range, they have an essentially NW—SE trend. Moreover, in the area of Gabal El Farayid and further north, they trend in an E—W direction.

b) Wadi El Miyah — Wadi Atalla geosynclinal zone: This zone is 170 km in length and its maximum width is about 100 km. The major structural trends here, follow a NNW—SSE direction.

c) Wadi Belih — Wadi Hawashiya geosynclinal zone: This zone is about 200 km in length with a maximum width of about 70 km. This width decreases down to about 10 km at its extreme northern part. The major structural trends in its northern part have an almost NNW—SSE direction, whereas in its southern part they follow a NE—SW directions.

2. Geoanticlinal Zones

Geoanticlinal zones represent the positive analogy of the geosynclinal ones [SHATSKY, 1946]. They are characterized by the relatively small thickness of their sequences and the presence of disconformities, differing in this respect from the geosynclinal zones which attain tremendous thicknesses and show no disconformities. The geoanticlinal zones are comparatively high areas which suffered from prolonged local uplifting during different geological ages and consequently they represent areas of erosion or areas of source material. They were intensively folded and the folds were dissected by sets of major and minor faults. Their rocks are generally dynamically metamorphosed. The geoanticlinal zones are usually separated from the adjacent geosynclinal ones by deep-seated faults along which huge amounts of submarine volcanic material were effused in the initial phase, and extensive masses of granitic rocks were intruded in the final phase of development of the eugeosynclinal system of the Eastern Desert. The main geoanticlinal zones in the area are:

a) *Gebel Abu Diab geoanticlinal zone:* This is composed of highly deformed granitic rocks with large masses of metavolcanics and metasediments thrown into a series of complex folds and further complicated by a system of faults. The major structural trends have a sublatitudinal direction. Gebel Abu Diab geoanticlinal zone is bordered from the north and south by deep-seated faults *(Fig. 1)*.

b) *Gebel El Shayeb geoanticlinal zone:* This zone includes Gebel El Shayeb, the highest mountain in the Eastern Desert (2184 m). The rocks outcropping here are mainly of granitic compositon, that suffered intense deformation during the evolution of this zone. Moreover, the sedimentary and volcanic formations present, were subjected to intensive weathering. The zone is bound by deep-seated faults from the north and south. The prevailing major structural trends follow an ENE—WSW direction.

3. Median Masses

Median masses play an important role in the development of the geosynclinal belts or systems. They differ from the geosynclinal and geoanticlinal zones not only in the rock types forming them or the degree of metamorphism to which they were subjected, but also in the fact that they belong to another major and older structure, which was formed prior to the present geosynclinal system. Their general characteristics were given by ARKHANGELSKY [1939], SHATSKY [1946] and KHAIN [1964] as follows:

i) They represent remnants of old platforms of highly consolidated parts of an older folded structure.
ii) They are stable and comparatively elevated masses within a mobile geosynclinal system.
iii) Their rocks suffered intensive regional and/or depth metamorphism.
iv) The form and shape of the median masses vary from nearly rounded or angular, to almost oval or almond-shaped in outline.
v) The formations of the geosynclinal system almost encircle the median masses leaving them as islands acting as the source area for the filling of the surrounding geosynclinal troughs.
vi) Median masses are usually bordered by deep-seated faults.

In the Eastern Desert of Egypt, three major median masses are encountered *(Fig. 1)*, these are:

a) Gebel Holwa — Gebel Seiga — Gebel Nigrub.
b) Gebel Migif — Gebel Hafafit.
c) Gebel Meatiq.

The pre-existing major median masses were broken up by systems of faults into separate blocks parts of which from the outcropping median masses of the Eastern Desert. Along these faults graben-like depressions were formed, filled with later geosynclinal formations. The general characteristics of these masses may be inferred from the best studied among them, namely Gebel Migif — Gebel Hafafit median mass. The unpublished map (scale 1:40 000) prepared by EL RAMLY shows this area to consist of a thick (4.2 km) succession of gneisses in the form of an eroded doubly plunging anticline some 55 km long and about 17 km wide. The succession of these gneisses is as follows:

Youngest

Dark green hornblende gneisses	1200 m
Grey biotite gneisses	800 m
Pinkish and grey psammitic gneisses	1000 m
Dark grey biotite-hornblende gneisses	500 m
Hornblende gneisses	400 m
Migmatitic gneisses	

Oldest

These rocks are mainly paragneisses metamorphosed after pelites, semipelites, calcareous pelites, psammites and marls. They are bordered from the north and east by a group of metasediments of a comparatively lower grade of metamorphism, including phyllites, meta-mudstones, meta-greywackes, schists and occasional conglomerates. The contacts examined, so far, between the gneisses and the surrounding meta-sediments do not reveal any obvious unconformity. Yet, there are considerable differences in lithology and degree of metamorphism that cannot be disregarded. Thus, it may be stated that the contact are of tectonic origin and follow deep-seated faults.

Gebel Meatiq median mass is mainly formed of paragneisses with some orthogneisses developed after intrusive rocks [AKAAD and SHAZLY, 1972 and SCHURMANN, 1966].

It may be generalized that the three median masses encountered in the eugeosynclinal system, were subjected to a high grade depth metamorphism and were intensively deformed. They probably belong to one and the same geological age presumably the Archean-Lower Proterozoic. They are bordered by deep-seated faults which are concealed in some places. Regional metamorphism accompanied by tectonic movements along these deep-seated faults affected the complex of formations developed later on, and gave rise to phyllites and schists which bound the median masses. Folds within the median masses are essentially domes, with few of the linear type. On the other hand, those of the eugeosynclinal system are mainly of the linear Alpine type.

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