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Author(s)	Taraz, Hooshang; Golshani, Farrokh; Nakazawa, Keiji; Shimizu, Daikichiro; Bando, Yuji; Ishii, Ken-ichi; Murata, Masafumi; Okimura, Yuji; Sakagami, Sumio; Nakamura, Koji; Tokuoka, Takao
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The Permian and the Lower Triassic Systems in Abadeh Region, Central Iran

By

Iranian-Japanese Research Group*

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Contents

Abstract

The continuous sequence of the Permian and the Lower Triassic Systems was fully examined paleontologically and sedimentologically in Abadeh region, Cenral Iran.

Based on the correlation of the Permian in the Tethys province by means of fusulinid, ammonoid and conodont zonations together with brachiopod, coral and bryozoan fossils, it is concluded that the Upper Permian is reasonably classified into three stages, the Abadehian, the Dzhulfian, and the Dorashamian.

Biostratigraphical and sedimentological study indicates a paraconformable relation between the Permian and Triassic, and the equivalent of the lower half of the *Otoceras woodwardi* zone is missing as judged from the conodont zones. The Dorashamian is older than the Griesbachian or Gangetian, and not the equivalent of the latter.

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* Hooshang TARAZ (present adress: San Diego, California, U.S.A.) and Farrokh GOLSHANI, of Geological and Mineral Survey of Iran; Keiji NAKAZAWA and Daikichiro SHIMIZU, of Kyoto University; Yuji BANDO, of Kagawa University, Ken-ichi ISHII, of Himeji Institute of Technology; Masafumi MURATA, of Kumamoto University; Yuji OKIMURA, of Hiroshima University; Sumio SAKAGAMI, of Chiba University; Koji NAKAMURA, of Hokkaido University; and Takao TOKUOKA, of Shimane University.

The faunal change is related to not only local environmental change but universal causes. A remarkable attrition of species began in the Dzhulfian and reached a climax at the end of the Permian. Almost all the species had disappeared by the end of the Permian corresponding to the progressive shallowing and retreat of the sea. Rapid transgression and incoming of new organisms at the beginning of the Triassic is evident in the lithofacies and biofacies of the Lower Triassic.

I. Introduction and Acknowledgments

"Probably few if any of our systemic boundaries are adequately defined in type areas of the present time, and stratigraphic progress is impeded by gaps and overlaps at these boundaries and by futile controversies over the placement of strata. Our crying need is far the careful designation and universal acceptance of limits in continuous type, or reference sections which can serve as standards for these systems. Without such definition we will have only endless arguments and continued chaos." (HEDBERG, 1961).

Probably one of the longest most confused arguments in the history of research on boundaries of the geologic systems pertains to the Permian-Triassic boundary and the Upper Permian biochronology. Many geologists, paleontologists and stratigraphers have contributed to this subject from the study of sequences over the world, but much confusion has arisen from incomplete sections and provinciality of organisms. The chronostratigraphic scale for the Permian, especially the upper part, is still under serious discussion and many contrasting proposals have been made for subdividing this geologic system (Table 1).

The Permian System presents difficult problems. So far, no definitely continuous marine sedimentary section or set of sections across the Permian-Triassic boundary have been found. Consequently a complete biostratigraphic scale in this part of the standard column is still lacking. It has been widely believed that a strange and almost world-wide regression occurred between the time of the latest Permian and the earliest Triassic resulting in a 'catastrophic' change of faunas at or near the boundary.

Lower Triassic sections with many organisms in common are found in various places in the world. General zonation by ammonoids, bivalves, and conodonts useful for international correlation has been established. Even so, nomenclatorial problems of chronostratigraphic classification still remain and a reliable range-chart is still lacking for the Upper Permian and the Permian-Triassic transition beds.

For a long time geologists have searched for a complete marine section which could be used as a standard. One promising example is known in South China, on which studies are now being advanced by Chinese scientists. Another is in Transcaucasia, where studies-in-depth were carried out by Soviet geologists (RUZHENTSEV & SARYCHEVA, 1965), but the *Otoceras* beds are not developed there and further micropalentological study seems to be required. The Kashmir section offers important data published by NAKAZAWA *et al.* (1975), but the Upper Permian faunas are not for world standard.

Table 1. Various schemes of classification of the Permian

<table>
<tr><th>Standard of USSR</th><th>Schenk et al. 1941</th><th colspan="2">Furnish, 1973</th><th>Stepanov, 1973</th><th colspan="2">Leven, 1975</th><th colspan="2">Waterhouse, 1976</th><th colspan="2">Kozur, 1977</th></tr>
<tr><td></td><td></td><td colspan="2"></td><td></td><td colspan="2"></td><td rowspan="4">Dorashamian</td><td>Gangetian</td><td colspan="2">Brahmanian</td></tr>
<tr><td rowspan="6">Tartarian</td><td rowspan="4">Djulfian</td><td rowspan="5">Dzhulfian</td><td rowspan="2">Changhsing.</td><td rowspan="5">Dzhulfian</td><td rowspan="8">Aryan</td><td rowspan="3">Changhsing.</td><td>Ogbinan</td><td rowspan="5">Dzhulfian</td><td rowspan="3">Dorasham.</td></tr>
<tr><td rowspan="2">Vedian</td></tr>
<tr><td rowspan="2">Chhidruan</td></tr>
<tr><td rowspan="2">Dzhulfian</td><td rowspan="3">Dzhulfian</td><td rowspan="2">Baisalian</td><td rowspan="2">Baisalian</td></tr>
<tr><td rowspan="2">Panjabian</td><td>Araksian</td></tr>
<tr><td rowspan="9">Guadalupian</td><td>Amarassian</td><td rowspan="4">Kazanian</td><td rowspan="3">Capitanian</td><td>Urushtenian</td><td colspan="2">Abadehian</td></tr>
<tr><td rowspan="4">Kazanian</td><td rowspan="8">Guadalupian</td><td rowspan="4">Capitanian</td><td rowspan="2">Pan-jab.</td><td>Chhidruan</td><td colspan="2" rowspan="2">Capitanian</td></tr>
<tr><td>Kalabaghian</td></tr>
<tr><td rowspan="8">Kushan</td><td rowspan="3">Murgabian</td><td rowspan="3">Kaza.</td><td rowspan="2">Sosnovian</td><td colspan="2" rowspan="3">Wordian</td></tr>
<tr><td rowspan="7">Svalvardia</td></tr>
<tr><td rowspan="2">Ufimian</td><td rowspan="4">Wordian</td><td>Kalinovian</td></tr>
<tr><td rowspan="3">Kubergandin.</td><td rowspan="3">Kung.</td><td rowspan="2">Irenian</td><td colspan="2" rowspan="3">Kubergandin.</td></tr>
<tr><td rowspan="3">Kungurian</td></tr>
<tr><td>Filippovian</td></tr>
<tr><td rowspan="4">Artinskian</td><td rowspan="4">Artinskian</td><td rowspan="2">Roadian</td><td rowspan="2">Chihsian</td><td rowspan="3">Baigenzin.</td><td rowspan="2">Krasnoufim.</td><td colspan="2" rowspan="2">Chihsian</td></tr>
<tr><td rowspan="3">Artinskian</td></tr>
<tr><td>Leonardian</td><td rowspan="2">Artinskian</td><td rowspan="7">Yaink</td><td rowspan="2">Artinskian</td><td>Sarginian</td><td colspan="2">Leonardian</td></tr>
<tr><td>Aktastinian</td><td rowspan="3">Sakmarian</td><td>Aktasitin.</td><td colspan="2">Artinskian</td></tr>
<tr><td rowspan="2">Sakmarian</td><td rowspan="5">Sakmarian</td><td rowspan="5">Sakmarian</td><td>Sterlitamak.</td><td rowspan="2">Sakmarian</td><td rowspan="2">Sakmarian</td><td>Sterlitam.</td><td rowspan="2">Sakmar.</td><td>Sterlitam.</td></tr>
<tr><td>Tatsubian</td><td>Tatsubian</td><td>Tatsubian</td></tr>
<tr><td rowspan="3">Asselian</td><td rowspan="3">Asselian</td><td rowspan="3">Asselian</td><td rowspan="3">Asselian</td><td rowspan="3">Asseli.</td><td>Kurmaian</td><td colspan="2" rowspan="3">Asselian</td></tr>
<tr><td>Uskalikian</td></tr>
<tr><td>Surenian</td></tr>
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A fine, nearly continuous section from the Artinskian to the Middle Triassic was discovered in 1967, by TARAZ, in Central Iran (Abadeh region). In a series of publications, TARAZ (1969, 1971, 1974) described the stratigraphy of the Abadeh section.

In 1972 an Iranian-Japanese Research Group consisting of geologists of the Geological and Mineral Survey of Iran and research staffs of several Japanese universities was organized and the first joint field survey was made in 1972. Supplementary field work was done in 1975. The present report is the result of a detailed paleontological and sedimentological study by the research group.

The field survey was carried out by the following teams, at that time with the indicated affiliations: H. TARAZ and F. GOLSHANI, of the Geological Survey of Iran; K. NAKAZAWA (chief of the Japanese team), D. SHIMIZU and T. TOKUOKA, of Kyoto University; Y. BANDO, of Kagawa University; K. ISHII, of Osaka City University; K. NAKAMURA, of Hokkaido University; M. MURATA, of Tohoku University; Y. OKIMURA, of Hiroshima University; and S. SAKAGAMI, of Ehime University.

The paleontological study was shared with NAKAZAWA (Bivalvia), ISHII and OKIMURA (Fusulinacea and smaller Foraminifera), GOLSHANI, SHIMIZU and NAKAMURA (Brachiopoda), BANDO (Cephalopoda), MURATA (Gastropoda and Conodontphorida), and SAKAGAMI (Bryozoa). The examination of corals was entrusted to Dr. M. KATO of Hokkaido University. The sedimentological study was performed by OKIMURA and TOKUOKA, and chemical analyses of boron and lithium were made by Mr. A. INAZUMI of Kagawa University. The editorial work was done by NAKAZAWA and TARAZ.

The cooperative works were made possible by financial aid of the Overseas Scientific Research Fund of the Ministry of Education, Japan, and the support of the Geological and Mineral Survey of Iran, Government of Iran. All the members wish to express their cordial appreciation to both governments for this aid. They are also obliged to the former Managing Director, Mr. R. ASSEFI of the Geological and Mineral Survey of Iran and the many collegues of the member's universities who helped in this study. Thanks are due to Dr. M. KATO for the information on the corals, to Mr. A. INAZUMI for chemical analysis, and to Dr. N. D. NEWELL of the American Museum of Natural History for reading the manuscript. Dr. J. M. DICKINS of Bureau of Mineral Resources of Australia, Dr. J. B. WATERHOUSE of University of Queensland, Dr. H. KOZUR of Staatliche Mussen, Meiningen, Dr. E. Ya. LEVEN of Geological Institute of Moscow, Dr. J. STÖCKLIN of Switzerland, and Drs. J. C. SHENG, C. C. CHEN and L. LIU of Nanjing Institute of Geology and Palaeontology, Academia Sinica gave helpful suggestions and informations. Lastly the members are obliged to the Government of Japan and the Japan Society for the Promotion of Science for supplying the fund to invite two Iranian members, H. TARAZ and F.GOLSHANI, to Japan for summarization of this work.

II. Geographical Location and General Geology of Abadeh Region

1. Geographical location

The continuous Permian-Triassic section of Abadeh is situated in Central Iran. Its name is derived from the town of Abadeh, Lat. 31°10′N and Long. 52°30′E (about 20,000 inhabitants) located some 200 km SSE of Esfahan along the main road from Esfahan to Shiraz (Figs. 1 and 3).

The Abadeh section, type locality of the Abadeh Formation lies in the Hambast Range (Ku-e-Hambast) which is located some 60 km SE of the town of Abadeh (Lat. 30°53′40″N, Long. 53°12′54″E). The Hambast Range with an average elevation of 2,000 m above the sea level has a desert climate, with hot summers and cold winters. The mountains exhibit bare rock outcrops with very little vegetation. The average rainfall is estimated at about 200–300 mm per year and snow falls on the higher parts of the Hambast Range during December and January.

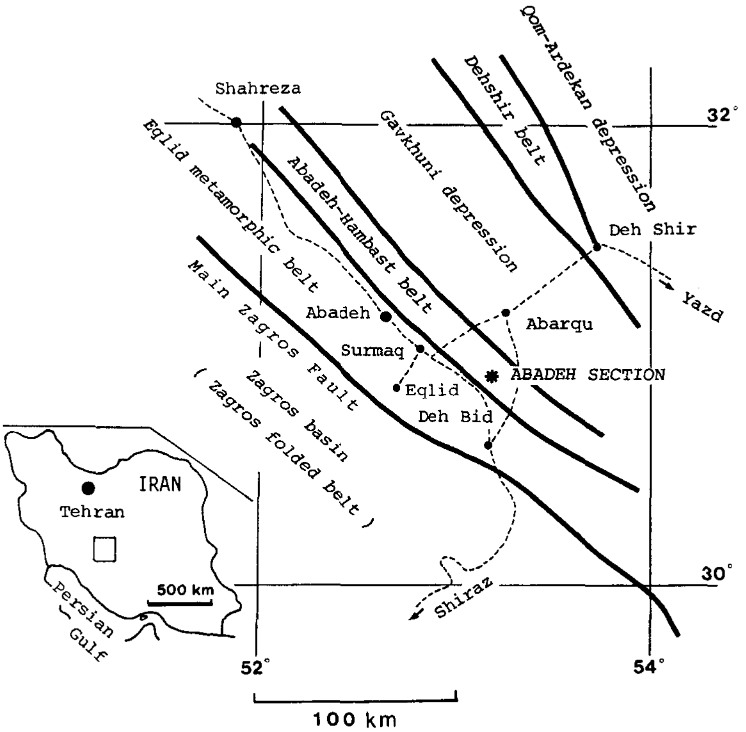

Fig. 1. Structural zonation of the Abadeh-Deh Bid area.

2. General geology

As shown on the geological map (Fig. 3) and simplified column (Fig. 4), grey, bedded, carbonate rocks and less shales of Permian age are exposed in the Hambast Valley where they are overlain by a long sequence of thin-bedded, light-grey limestones and shales, of the Lower Triassic, and massive, thick dolostones of probable Middle Triassic age. Tectonic disturbance in the area is limited to faulting and the general structure is simple. The Abadeh section was measured and investigated in the Hambast Valley area.

An important new discovery pertaining to the geologic structure of the Abadeh region is a horst-graben system which existed in Precambrian time and has since been active. Fig. 1 shows the location of the faults and Fig. 2 shows the stratigraphic columns and sedimentary gaps in each fault basin.

The main tectonic feature of Iran is a persistent linear fault zone which crosses approximately at the watershed of the Zagros Mountain Range in a NW–SE direction

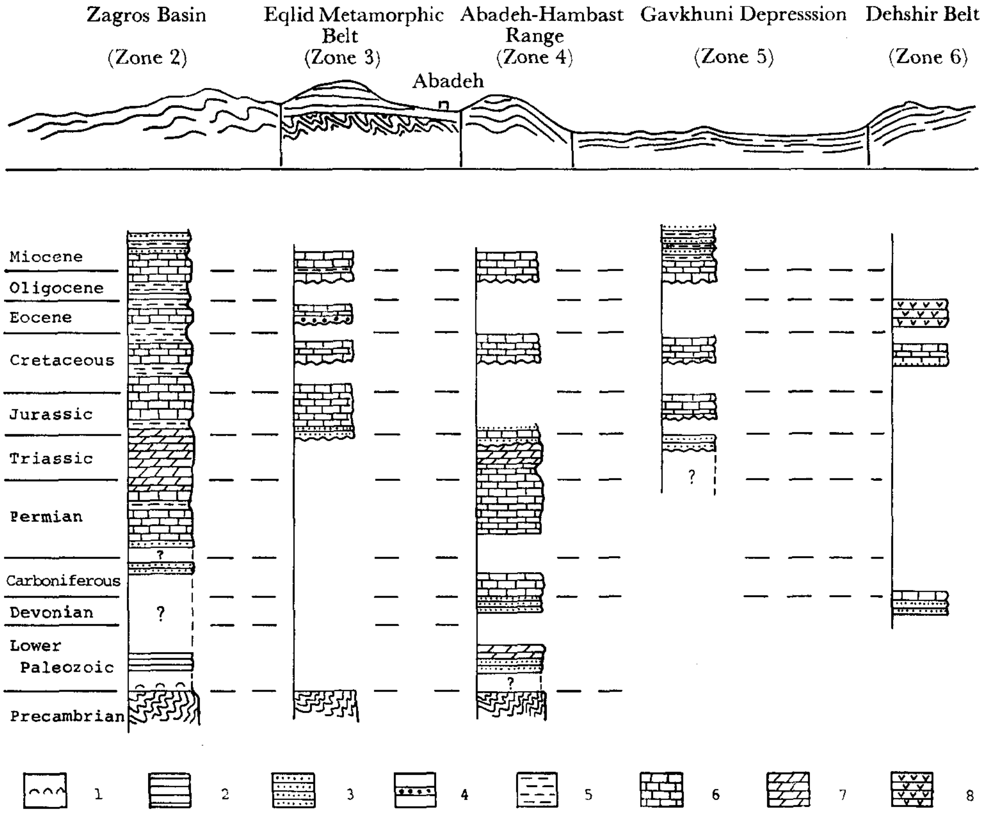

Fig. 2. Geological columnar sections of each structural zone.

Main lithofacies, 1: evaporite, 2: shale, 3: sandstone, 4: conglomerate, 5: "marl", 6: limestone, 7: dolostone, 8: pyroclastic rocks.

and separates the Zagros folded belt from the Arabian Plateau in the southwest, and from the Central Iran region in the northeast. It is known variously as the Zagros Thrust Line, Main Zagros thrust, Zagros thrust, etc. This is the same fault shown on Fig. 1 between the Zagros basin (Zagros folded belt) and the Eqlid metamorphic belt. Stöcklin (1968) in his discussion of the thrust line wrote (p. 1247), "The main Zagros thrust has a remarkably straight alignment and is considered to be a surface expression of deep slip in the formerly coherent Arabian-Iranian platform. The rigid Precambrian basement in the thrust zone is buried deeply below the Paleozoic platform cover and thick younger trough deposits. Just northeast of the thrust line an extensive metamorphic complex is exposed, part of which is Precambrian (Thiele *et al.*, 1967). Similar Precambrian basement rocks reappear farther northeast in Central and North Iran. The main Zagros thrust is thus a deep reverse fault, splitting a once-coherent platform into an Arabian and an Iranian fraction. The first evidence for the partition originated in Infracambrian time, when a gentle, southwest-facing slope along the later thrust line limited the Hormuz Salt basin on the northeast."

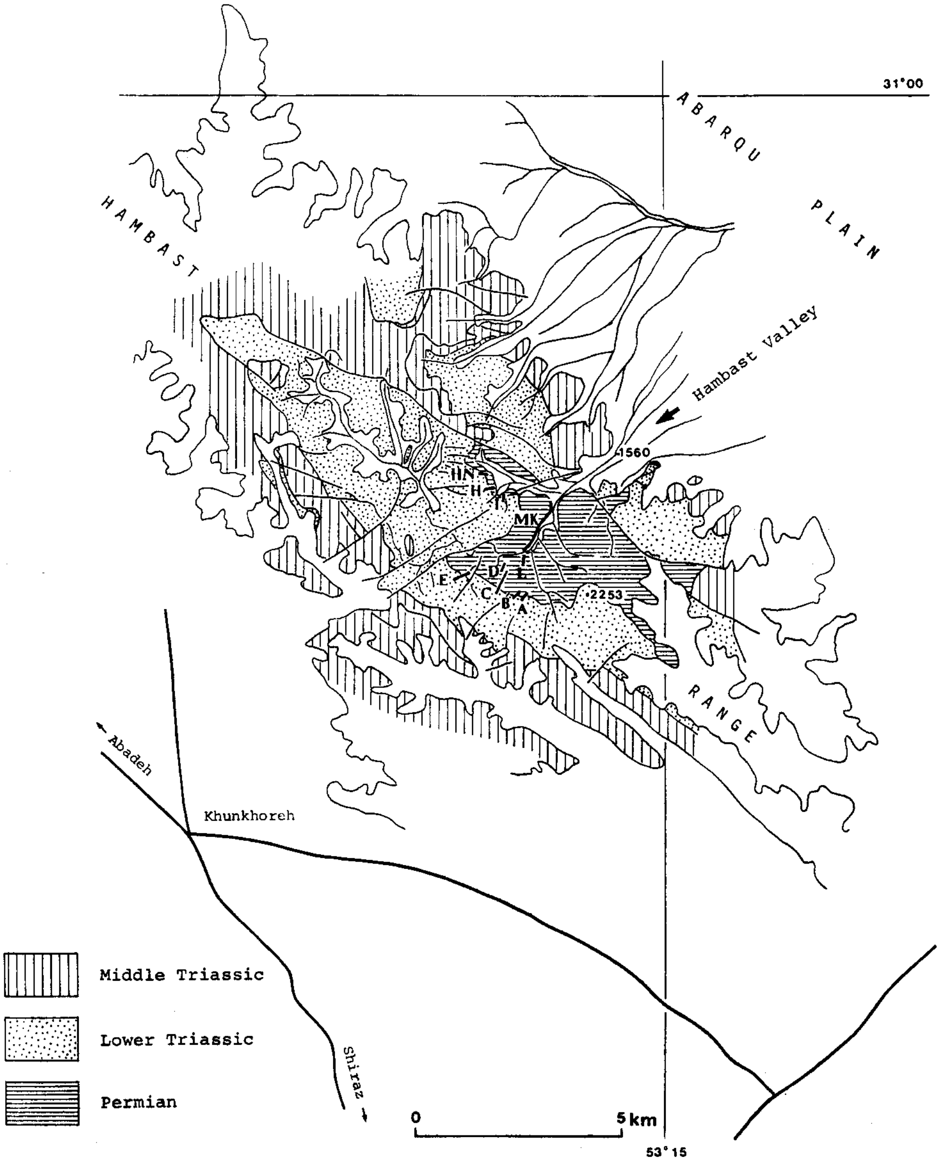

Fig. 3. Generalized geological map around surveyed area. (Adapted from TARAZ, 1974).

Observation of this fault zone at several localities along 400 km from Neyriz to Borujerd in Iran, however, shows that it is nearly vertical, about 3 to 5 km wide and intensively crushed. It came into existence during Infracambrian time and has been reactivated during several geological periods. The existing vertical displacement along this fault is estimated over 5,000 m. Further investigation shows that it has been an active horst-graben system since the Infracambrian. Thus there are good reasons to reject the idea that this zone is a thrust fault. Therefore, it is here referred to only as the main Zagros fault. Along this fault, in several places in Oman, Iran and Turkey, the colored melange is exposed indicating that this fault zone is the surface expression of a closed plate collision zone with an oceanic crust.

The stratigraphic columns in the two sides of the main Zagros fault are very different. As shown in Fig. 2, the Paleozoic and Triassic formations which are exposed in the Zagros basin, are missing in the Eqlid metamorphic belt where Lower Jurassic sandstones and shales lie directly on metamorphosed Precambrian basement, indicating a sedimentary gap for the Paleozoic and Triassic Periods. The Eqlid belt is about 30 km wide and extends to NW and SE for over 500 km and 200 km, respectively. The Lower Cretaceous, Paleocene, Oligocene and Upper Miocene deposits are missing, too, in the Eqlid belt indicating that it was a horst during the Paleozoic and Triassic, then became a graben in the Jurassic. It was uplifted and subsided several times, during Mesozoic and Tertiary Periods.

The next fault separates the Eqlid metamorphic belt from the Abadeh-Hambast belt. It is a straight, vertical fault. The vertical displacement is estimated at over 3,500 m. The stratigraphic columns on the sides of this fault are also very different. Lower Paleozoic dolostones and quartzitic sandstones are exposed in the Abadeh-Hambast belt. The Lower Devonian is missing but Upper Devonian and Lower Carboniferous limestones and sandstones are exposed. During the late Carboniferous and early Permian this belt was uplifted as a horst but at the late Sakmarian it subsided and a thick series of limestone and dolostone with some shale of the Permian-Triassic of Abadeh accumulated in the graben. Jurassic sediments are completely missing in this belt as a sedimentary gap and it evidently was a horst during the Jurassic and early Cretaceous. Aptian to Cenomanian limestones are exposed here and another sedimentary gap occurs from the late Cretaceous to the Middle Oligocene. Upper Oligocene and Lower Miocene limestones with an angular unconformity were deposited in this belt. Most probably this belt became a horst since the Middle Miocene. The Abadeh-Hambast belt is about 25 km wide and extends NW and SE over 300 km and 150 km, respectively.

A fault also separates the Abadeh-Hambast belt from the Gavkhuni depression. This depression is a part of a larger depression which is more or less parallel to the main Zagros fault, northeast of the Abadeh-Hambast belt. It occurs in southeast of Iran (Baluchestan) as the Jaz Murian depression and extends to northwest as the Sirjan depression (SW of Kerman), as the Gavkhuni depression (SE of Esfahan), as the Tuzlü Göl depression (north of Arak) and probably as the Rezaiyeh depression (SW of Tabriz) (Tectonic Map of Iran, 1: 2,500,000, by STÖCKLIN and NABAVI, 1973), the length of which is over 1,800 km. The width of this belt in the Abadeh region is about 60 km. As shown in Fig. 2, the stratigraphic column of the exposed rock formations in this belt is very much different from the neighbouring blocks on the SE and NE sides. Some Upper Triassic volcanic rocks occur in this belt. They are missing in the Abadeh-Hambast belt. The Lower Jurassic has not been found, but Middle to Upper Jurassic limestones are exposed. The Lower Cretaceous is represented by a sedimentary gap but Aptian to Cenomanian limestones were deposited in this belt. The Eocene strata are completely lacking and the belt had been as rising horst during the late Cretaceous, Eocene and early to middle Oligocene times. The belt subsided during the late Oligocene and became a large graben in which the Upper Oligocene to Middle Miocene limestones, conglomerates and some evaporites of the Middle Miocene to Pliocene age were deposited.

A fault separates the Gavkhuni depression from the Dehshir belt (Fig. 1). Topographically, the Dehshir belt is an elevated block of low hills, a range, which extends farther to the northwest. It is cut by another fault near Dehshir village. The oldest rocks exposed are a series of quartzite, dolostone, shale and limestone of probably Devonian age. The Upper Paleozoic, Triassic and Jurassic are missing in this belt. The Aptian limestones crop out in isolated hills, so the contact with other rocks is not clear. A Lutetian transgression is shown by beds of conglomerate and sandstone overlain by a thick series of acid to intermediate volcanic flows and pyroclastic rocks. Many acid and intermediate rocks also intrude through this series. These volcanics are of Eocene and Oligocene age. Post-Eocene sedimentary rocks are absent in this belt. Most probably it has been emergent since Oligocene time. Surprisingly, the volcanic facies of the Dehshir belt is absent in the Gavkhuni belt from the Jaz Murian depression in the southeast to the Rezaiyeh depression in the northwest. It is also missing everywhere southwest of the Gavkhuni belt.

The Dehshir belt is part of a very long and distinctive volcanic and intrusive belt extending more or less in a straight line parallel to the Jaz Murian — Rezaiyeh depressions. We call it the Central Iran volcanic belt. It is over 1,300 km long and about 60 km wide. To the northeast of this volcanic belt another long, and relatively narrow depression, the Qom-Ardekan depression exists.

The boundary faults of the above-mentioned belts are more or less parallel with a general NW-SE trend. The data of Figs. 1 and 2 suggest that the Abadeh region and its surroundings have a fault-block pattern, consisting of horsts and grabens active since Infracambrian time. They also show that a similar fault-block and horst-graben system exists, if not all over Central Iran, at least in many areas, including east Semnan (ALAVI, 1972; ALAVI & FLANDRIN, 1970), Tabas (STÖCKLIN *et al.*, 1965b; RUTTNER *et al.*, 1968), Zanjan (STÖCKLIN *et al.*, 1965a), etc. This horst-graben system is an answer to many of our questions concerning the geology of Central Iran: why are the Permian-Triassic sections of Abadeh and Julfa so much alike, and why are both so much different from those of east Central Iran (Tabas area)? Apparently they belong to a single NW trending basin but separated from other basins by horsts.

III. Permian and Triassic Systems in Iran — A Review

1. Historical review of Permian-Triassic research in Iran

The Abadeh region and the area to the southwest was mapped and investigated by geologists of the former Anglo-Iranian Oil Company in 1935–1936 (HARRISON *et al.*, internal report) and the results were published on a 1 : 250,000 Geological Map Series of Iran by the British Petroleum Company, Ltd. in 1963 and 1964. The Permian and Triassic formations of the Hambast and Abadeh region are shown, and the geological report of the area dealing mainly with oil exploration was considered as a classified report not for publication. Very short descriptions were given of the Permian and Triassic rocks in the Abadeh region and the existence of a continuous Permian-Triassic section was not appreciated. TARAZ visited the area in 1967 and recognized its relative completeness and rough evaluation of this section was published by him in 1969. The results of more detailed investigations were then published in 1971 and 1974.

The history of research on the Permian-Triassic sequences in Iran goes back to 1965, when the results of a detailed investigation of the Dzhulfian stratotype in the Dzhulfa region (Dorasham), north of the Arax River in U.S.S.R., was published (RUZHENTSEV & SARYCHEVA, 1965). At that time the Geological Survey of Iran decided to make a detailed investigation of the Permian-Triassic beds near the town of Julfa, south of the Arax River. The results of this research were printed in 1969 (STEPANOV *et al.*).

Before 1965 many geologists had mentioned the occurrence of the Permian and the Triassic outcrops in different parts of Iran, without specific attention to the geological and paleontological characteristics of the Permian-Triassic boundary. FRECH (1906) reported the presence of the Permian rocks in eastern Alborz Mountains. STAHL (1911) reported Upper Paleozoic rocks in few localities in North Iran. Geologists of the former Anglo-Iranian Oil Company have done tremendous geological mapping for oil exploration in Zagros and the south-western part of it in Iran and they reported many outcrops of the Permian and Triassic beds. RIEBEN

(1934) also reported the presence of Upper Permian limestone and Triassic platy limestone in several localities in Iranian Azerbayjan. RIVIERE (1934) also mapped and described anthracolithic limestone (Upper Paleozoic) and Triassic rocks in the Alborz Mountains. ASSERETO (1963) gave more details about the Permian strata in Alborz (Dorud Formation and Ruteh Limestone) and GLAUS (1964, 1965) correlated the Upper Permian Nesen Formation in Alborz with the Dzhulfian. Many paleontologists also contributed by studying rock samples of the Upper Permian formations in Iran collected by field geologists.

After the discovery of the Abadeh section in 1967, the Geological Survey of Iran made arrangement for cooperation with the Japanese universities to make a detailed paleontological study of that section. The results of that study are published in this report.

2. Chronostratigraphic problems of the Permian-Triassic in Iran

RUZHENTSEV and SARYCHEVA (1965) classified the Permian-Triassic transition beds as follows, in descending order.

Induan (Early Eo-Triassic)
  1. *Claraia* beds
  2. *Paratirolites* beds
  3. *Bernhardites* beds
  4. *Dzhulfites* beds
  5. *Tompophiceras* beds

Dzhulfian beds (Late Permian)
  6. *Phisonites-Comelicania* beds
  7. *Vedioceras-Haydenella* beds
  8. *Araxoceras-Oldhamina* beds
  9. *Araxilevis-Orthotetina* beds
  10. *Codonofusiella-Reichelina* beds

Khachik beds (Guadalupian)

They placed the Permian-Triassic boundary at the base of the *Tompophiceras* beds and the base of the Dzhulfian at the base of the *Codonofusiella-Reichelina* beds. Previously GLENISTER and FURNISH (1961) had proposed a global subdivision for the Permian which cosisted of Lower and Upper Permian, and divided the Upper Permian into two stages, a lower–Guadalupian and an upper–Dzhulfian. RUZHENTSEV and SARYCHEVA accepted this subdivision and applied it to the Dzhulfa section.

STEPANOV *et al.* (1969) described in detail the Kuh-e-Ali Bashi section in Iranian Julfa and found that this section can be correlated closely with the stratotype section of Dzhulfian Stage in Armenia. Accordingly, they also accepted the same biostratigraphic divisions as RUZHENTSEV and SARYCHEVA, adopting Guadalupian and Dzhulfian Stages, but did not agree with them about the base of the Dzhulfian. They preferred the *Codonofusiella-Reichelina* beds as the uppermost part of the Khachik beds and consequently, the *Araxilevis-Orthotetina* beds as the base of the Dzhulfian, accepting the opinion of ARAKELIAN *et al.* (1964). They also introduced the Permian-Triassic transition beds for the interval from the *Phisonites* beds to the *Bernhardites* beds (Unit E). The Early Triassic Induan age of the *Tompophiceras* to *Paratirolites* beds were later referred to as the latest Permian by CHAO (1965), TOZER (1969) and later authors. ROSTOVTSEV and AZARYAN (1973) proposed a new stage name, Dorashamian, for this part. The Dorashamian beds in Julfa of Iranian border were reexamined by TEICHERT and KUMMEL (1973) and were named the Ali-Bashi Formation. At the same time, KUMMEL emended *Tompophiceras* as *Iranites*, *Bernhardites* as *Shevyrevites*, and included *Dzhulfites* and *Abichites* in *Paratirolites.*

In the history of the Permian-Triassic research in Iran, the papers of RUZHENTSEV and SARYCHEVA (1965) and STEPANOV *et al.* (1969) had been actually used as a base by many geologists. STÖCKLIN, NESHAD and ZADHE (1965) in the Tabas area of the Shotori Range in east Central Iran found the Permian limestone of the Guadalupian age overlain by red shale which is correlated with the Lower Triassic vermicular limestone. RUTTNER *et al.* (1968) also found the same sequence in the Shirgesht area, north of Tabas. In the Alborz Range, also, similar Guadalupian limestones have been mapped and described. ASSERETO (1963) produced two main subdivisions of the Permian rocks; the Dorud Formation of the early Permian and the Ruteh Limestone of the early Late Permian or Guadalupian age. GLAUS (1964, 1965) used also Guadalupian and Dzhulfian Stages and found a series of dark grey limestone in Nesen Valley of Central Alborz Mountains. From post-Guadalupian fossils that he found he correlated this (Nesen Formation) with the Dzhulfa beds. Surveying the Abadeh section TARAZ (1971) agreed with STEPANOV *et al.* (1969) that the *Araxilevis-Orthotetina* beds should be taken as the base of the Dzhulfian. He (1973) also recognized an erosional surface on bed No. 33 of STEPANOV *et al.* and insisted the presence of a great sedimentary gap between the bed No. 33 (*Codonofusiella-Reichelina* beds) and the overlying bed No. 34 (the base of the *Araxilevis-Orthotetina* beds). The Permian-Triassic sequence in Abadeh was divided into 12 units by TARAZ (1971, 1974) of which Units 6 and 7 are certainly correlated with the Dzhulfian (s.l.). The interval from Unit 1 to the lower part of Unit 3 were referred by him to the Artinskian-Guadalupian and the upper part of Unit 3, characterized by *Staffella* spp., as transitional. He concluded that Units 4 and 5 called the Abadeh Formation are post-Guadalupian and pre-Dzhulfian in age, and proposed a new stage name, Abadehian.

The Abadehian Stage was accepted by NAKAZAWA and KAPOOR (1977) based on preliminary results of the Iranian-Japanese joint work. KOZUR (1977) also adopted this stage name, but WATERHOUSE (1976a) preferred the Urushtenian Stage for the Abadehian, because of insufficient paleontological characteristics in the latter. Therefore, the validity of the Abadehian Stage is one of the subjects to be given special attention in this paper besides the problem of the Permian-Triassic boundary.

Very recently, conodont zonation of the uppermost Permian in Transcaucasia and Iran (including Abadeh), was published by KOZUR *et al.* (1978). Von F. and G. KAHLER (1979) reported Permian fusulinids from several places in Central and North Iran. A part of our collection has already been published, that is, Permian and Lower Triassic ammonoids by BANDO (1979), Lower Triassic *Claraia* by NAKAZAWA (1977), two trilobite species by KOBAYASHI and HAMADA (1978), and the Permian Bryozoa by SAKAGAMI (1980).

IV. Stratigraphy and Lithology of the Permian and Lower Triassic Strata in Abadeh Region

The Permian and the Lower Triassic rocks were first classified by TARAZ (1969) into twelve units, among which Units 1 to 7 belong to the Permian and Units 8 to 12 to the Lower and Middle? Triassic. Later he (1974) emended Units 8 to 12 as Units a to e, respectively. At the same time he divided the pre-Permian strata into two groups, the Limestone Group and the overlying Sandstone Group. The Limestone Group, more than 280 m thick, contains some corals which indicate an early Carboniferous age, but the Sandstone Group, 131.6 m thick, is represented by regressive facies and barren of fossils except for some gastropod fragments. Therefore, the age of the latter group is uncertain, but presumably late Carboniferous, though an early Permian age cannot be ruled out.

A transgression took place at the beginning of Artinskian time and deposited thick limestones with shales and cherts. The total thickness of the Permian attains to more than 1,100 metres. The seven Permian units mentioned above can be grouped into three formations on the basis of their lithologic nature, namely, the Surmaq, the Abadeh, and the Hambast Formations in ascending order (Fig. 4). The Surmaq Formation (Units 1 to 3), more than 450 m thick, is mostly made of grey limestones intercalating with some chert bands or nodules and shales. The next, the Abadeh Formation, about 458 m thick, consists of black shales and a minor amount of dark grey to black, thin-bedded limestones, in alternation. The Hambast Formation (Units 6 and 7) is 35 m thick, composed of variegated rocks, such as grey and reddish limestones and greenish and reddish shales.

TARAZ (1974) named the Lower Triassic beds the Limestone Group and the Middle Triassic the Dolomite Group, of which the former reaches 682 m in total thickness, and consists mostly of thin-bedded, grey to yellow limestones and shales.

The geologic structure of the surveyed area is somewhat complicated. It is characterized by open folds which stretch in a NW–SE direction and are cut by vertical or steeply dipping faults accompanied by nearly horizontal thrust faults, but the sequence is easy to trace for a long distance.

Detailed measuring and rock- and fossil-sampling were performed along ten sections in the Hambast Valley and a supplementary one (Lat. 31°03′N; Lon. 52°55′E) was studied and sampled near Surmaq.

The surveyed sections are as follows (Fig. 3);

	Section	Surveyed units
Hambast Valley	A	6, 7, a
	B	a
	C	4b, 5, 6, 7, a
	D	3, 4a
	E	2, 3, 4a
	H	5, 6, 7, a
	HN	4, 5, 6
	I	a
	L	2, 3
	MK	1
Surmaq	NR	1, 2

1. Surmaq Formation

1. *Unit 1*

Unit 1 was measured and examined at two localities, namely, about 5 km northeast from Surmaq, and along Hambast Valley. The base of the unit is not exposed at either site.

It can be observed, however, at Estaki mine, 8 km northeast of Abadeh, where a supplementary fossil collection was made (see Text-fig. 4 of TARAZ, 1974). This unit is characterized by a predominance of limestones which consist of thin-bedded (in beds 10 to 20 cm thick) and thick-bedded (in beds more than 30 cm thick) limestones in alternation containing thin layers of chert and shale. The thickness at Surmaq section is about a half that of Hambast Valley, as judged on the basis of fusulinid zone. The lithofacies is similar in both areas.

Hambast Valley section (Section MK, Fig. 6)

Unit 1 at Hambast section attains about 390 m in the measured portion. The lower part, about 120 m thick, is alternating thin-bedded limestone, thin, brownish shale layers, and thick-bedded, massive limestone. Thin beds of chert and nodules

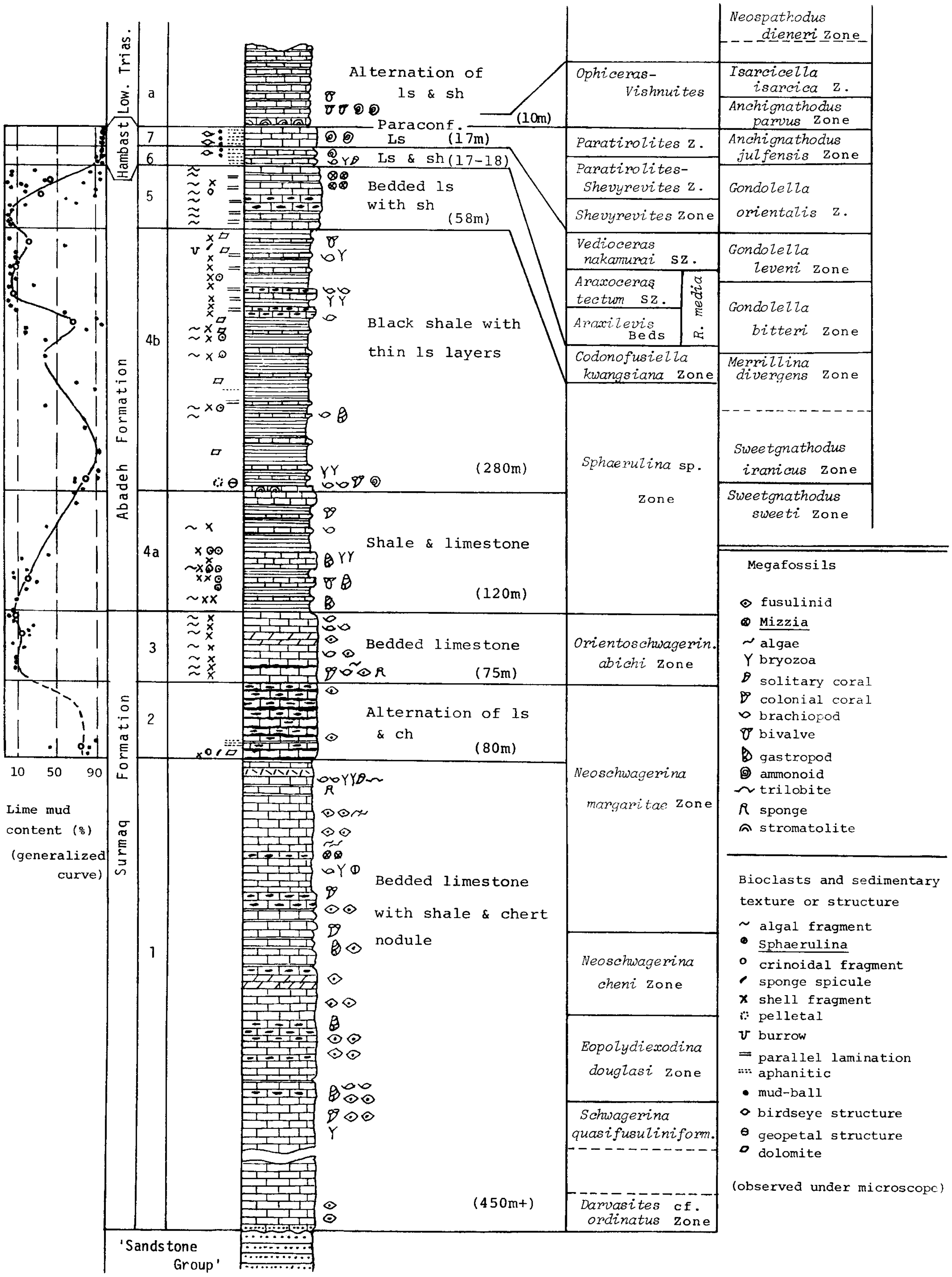

Fig. 4. Generalized columnar section of the Permian-Lower Triassic in Abadeh region showing fusulinid and conodont zones, fossil occurrence, sedimentary texture and lime-mud content.

are interbedded at several horizons mainly with thick-bedded limestones. The middle part, about 200 m thick, consists mostly of thin-bedded limestones in beds less than 30 cm thick intercalating with thin red shales and chert nodules in the middle. The upper part, about 70 m thick, is composed of thick-bedded limestones in the lower half and thin-bedded limestones with red shales and some chert nodules in the upper half, the latter of which merge into red tuffaceous rocks of about 9 m in thickness. Fossiliferous beds containing abundant macrofossils, especially brachiopods, are found beneath the tuffaceous rocks. Most of the limestone thin-sections collected for microfossils show fusuline biomicrite or biomicrudite.

Surmaq section (Section NR, Fig. 5)

Unit 1 at Surmaq section, more than 240 m, was measured. It is lithologically similar to that of Hambast Valley, but the limestone bedding planes are wavy.

The upper part is characterized by frequent intercalations of calcareous shale in relatively thin-bedded (10 to 30 cm thick) limestones, and differs from the equivalent part of Hambast section in lacking tuffaceous rocks and chert nodules. The limestones are mostly fusuline biomicrite or biomicrudite as in the Hambast area. Intraclasts are commonly found in the micritic matrix of those in the lower part, and algal fragments in the upper part. The limestones in the middle part (from Hor. N10 to R1, about 30 m thick) contain intraclasts and coralline algal fragments in sparry calcite cement. These may represent beach sands.

2. *Unit 2* (Figs. 6 and 7)

Unit 2 is characteristically dominant in chert and makes conspicuous cliffs. A complete sequence was measured on a cliff at the middle of the Hambast Valley, where the strata strike N75°W and dip around 30°NE. The total thickness is about 80 m.* This unit conformably overlies Unit 1 and along Section L it can be divided into four subunits based on the amount of chert, as follows.

Subunit *d*...Alternations of chert and limestone in beds several tens of centimetres thick, chert/limestone ratio 2: 1. Thickness of the chert is variable.

Subunit *c*...Alternation similar to *d*, but limestone more predominant.

Subunit *b*...5 to 10 cm-bedded limestones with discontinuous chert and nodular or lenticular chert.

Subunit *a*...Thick-bedded limestones with rare chert nodules.

The petrographic characters of the limestones change in accordance with lithofacies changes represented by the above-mentioned subdivisions. Limestones of subunits *a* and *b* are fine- to medium-grained biomicrite, and in most cases they

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* TARAZ (1969, 1974) estimated the thickness of Unit 2 at 260 m, but this large value is caused by fault duplication.

contain shell- and crinoid fragments and in some cases sponge spicules (Pl. 3, Fig. 2). Those of subunit *c* and *d* are predominant in chert, and generally are strongly recrystallized. The so-called "clotted" limestones much altered by silicification and dolomitization are common (Pl. 3, Fig. 3).

3. *Unit 3* (Fig. 7)

This unit is composed mostly of black limestones about 80 m thick. The complete section was measured and observed at Section L. The lower part, 19 m thick, consists of thick-bedded limestone in beds 50 to 100 cm thick intercalated with three chert layers more than one metre thick. The limestones are more or less dolomitized. The rest of the unit is made of an alternation of thin-bedded and thick-bedded limestones. The thin-bedded limestones usually have wavy bedding planes in brownish-grey, marly limestone.

The sedimentary petrographic characters are somewhat different between thin-bedded and thick-bedded limestones. The former approaches grain-supported micritic limestone. The grain-size is variable and bioclasts present are also variable as to kinds (Pl. 3, Figs. 4 and 5). On the other hand, the latter group contains mud-supported bioclasts, mostly of algal fragments, and are lithologically similar to that of Unit 4. Macrofossils are usually contained in the thin-bedded limestones, but foraminifers are equally common in both limestone facies.

2. Abadeh Formation

The Abadeh Formation is characterized by a thick development of black, flaggy shales, but the uppermost part contains more limestone. Consequently, the limy part is separated as Unit 5 from the main part of the formation (Unit 4).

1. *Unit 4* (Fig. 7)

This unit, about 400 m thick, is subdivided into two parts, 4a and 4b. Unit 4a has more limestone than Unit 4b, with a shale/limestone ratio around 1: 1.

Unit 4a

The part was originally included in Unit 3 by TARAZ (1969), but it is composed of alternations of shale and limestone. Lithologically it is more like Unit 4, hence it is considered here to be the lower division of Unit 4. The limestones are almost mud-supported biomicrite containing shell- and algal fragments. They are mostly massive and in part weakly laminated.

Unit 4b

Unit 4b corresponds to Unit 4 of TARAZ. It consists of black, flaggy shales and calcareous shales with thin limestone interbeds. Limestone layers are a little more prominent in the middle part where they are accompanied by discontinuous chert layers or nodules, and beds in the upper part become thicker. Micritic limestone at the base of the unit is accompanied by mat-like algal biolithite and contains abundant macrofossils (Pl. 3, Fig. 6). This bed is traceable and a useful key bed. Limestones of the lower 80 m part are usually mud-supported, but bioclasts are fine-grained and difficult to identify. On the other hand, those in the upper 100 m part are mainly grain-supported micritic limestone, in which bioclasts are mostly represented by dascycladacean fragments.

Texturally, two kinds of biomicrite can be distinguished, one has a parallel arrangement of shell and algal fragments (Pl. 4, Figs. 1 and 2). It sometimes shows graded texture and bioturbation (Pl. 4, Fig. 3). The other is characterized by a mixture of bioclasts of various sizes, mostly algal fragments (Pl. 3, Fig. 8).

2. *Unit 5* (Fig. 7)

Unit 5, about 58 m thick, consists of bedded, cliff-making limestones in the middle, and limestone-rich alternations in the lower and upper parts. Limestones of the lower 15 m are stratified algal biomicrite. The mud-supported biomicrite tends to increase upwards. Black, massive micritic limestones of the upper part contain scattered fragments several millimetres in size of dascycladacean algae.

3. Hambast Formation

1. *Unit 6* (Fig. 8)

Unit 6, 17 to 18 m thick, is composed of alternations of greenish shale and grey massive micritic limestone. The limestones contain a few bioclasts and have wavy or irregular bedding surfaces (Pl. 2, Figs. 2 and 3). Bioclasts of the lower part of the unit are made of shell and crinoid fragments. Vermicular limestone is rarely found in the lower part. Intramicrite or micrudite similar to those of Unit 7 are sometimes interbedded.

2. *Unit 7* (Fig. 8)

Unit 7 is about 17 m thick and represented by thin-bedded brownish-red limestones having nodular or wavy bedding surface. Nodular limestones sometimes look like an aggregate of intraclasts of gravel-size. The limestones of this unit are all micritic and under crossed nicols many of them are shown to be heterogeneous micritic limestone with a mud-ball structure (Pl. 4, Figs. 6 and 7). Limestone having birds eye structure is also confirmed at many horizons (Pl. 4, Fig. 8).

4. Lower Triassic (Unit a)

The Triassic rocks are composed mainly of carbonate rocks (Figs. 10 and 14) which TARAZ (1974) divided into two groups, the Lower Triassic Limestone and the Middle Triassic Dolomite. He further distinguished five units in the Limestone Group (Units a to e). The lowermost Unit a, about 90 m thick, consists of yellow to grey, more or less vermicular limestones and shales in beds several centimetres thick. The lower part of Unit a, 20 to 52 m in thickness, was measured and examined along several sections in the Hambast area. The sedimentological observations were made principally on the sequence of Section C (Figs. 10 and 14).

The examined part of Unit a is composed of thin-bedded alternations of limestone and greenish or yellowish shale with thin-bedded limestone intercalations, making a small cliff. The limestones are hard, grey-colored, and massive or parallel laminated, and they are frequently burrowed by worms, the vermicular limestone of TARAZ (1974). The texture is micritic, and the insoluble residue is usually less than 10%. The primary texture has generally been obscured by secondary crystallization and dolomitization. Sole markings and ripple marks are sometimes present.

The basal part of the unit (Beds 1 and 2), about 2 m thick, forms a small cliff which can easily be traced over whole the surveyed area. This part consists of thin-bedded limestone and stromatolitic one, and was called the colonial limestone in the field. Claraias and ophiceratid ammonoids are common above this bed, but mostly they are badly preserved.

5. Boundary between Unit 7 and Unit a

The Permian-Triassic boundary is located at Unit 7-Unit a boundary, and the special attention was paid to the succession of the transitional part at Sections A, C, and H (Fig. 11). The uppermost part of Unit 7 consists of thin-bedded pinkish limestones with thin shale interbeds in some places. The typical Dorashamian ammonite, *Paratirolites*, is found up to the top of Unit 7. It is confirmed that there exists everywhere a thin, brownish or greenish shale bed, 10 to 30 cm thick, in between the *Paratirolites* limestone and the stromatolitic limestone. This shale bed sporadically contains solitary stromatolitic bodies and thin pinkish limestone layers. The relation of the shale bed and the overlying stromatolite beds is gradational and the shale bed is referred to as the base of the Triassic. Most probably it corresponds to the purplish shale bed at the base of the Elikah Formation (bed 62 of Unit G of STEPANOV *et al.*, 1969) in Julfa region.

No erosional feature could be observed between this and the underlying

Paratirolites beds and seemingly they are conformable, although a time gap is deduced from the biostratigraphical and sedimentological study. An example of the details of the transition is shown below, in discending order.

Lower Triassic		
g)	grey stromatolitic limestone	
f)	fine-grained, grey limestone with brownish muddy lamina or patches	3 cm
e)	deeply weathered, very fine-grained micritic limestone	4 cm
d)	irregularly bedded greenish limestone	1 cm
c)	pale-brownish shale	12 cm
Permian		
b)	thin-bedded alternation of pinkish limestone and greenish shale in beds 1–2 cm thick	15 cm
a)	thin-bedded variegated limestone	

V. Fauna and Biostratigraphy

1. Unit 1

According to Taraz (1974) the thickness of Unit 1 is estimated at more than 450 m. The upper 240 m near Surmaq (Section NR) and 390 m along Hambast Valley (Section MK) were examined.

Surmaq section

Unit 1 of this section has abundant fusulinids, by which the zoning is made possible. As shown in the range-chart (Fig. 5) the lowermost part (Hor. P2 to Hor. N1), 30 m thick, is characterized by the association of *Eopolydiexodina douglasi* and E. *bandoi*, n. sp. accompanied with *Rugososchwagerina*? sp., *Afghanella schencki* and *Verbeekina verbeeki*. This part can be distinguished as the *Eopolydiexodina douglasi* Zone.

The next 90 m part (Hor. N2 to Hor. N12) contains various kinds of fusulinids, such as *Yangchienia haydeni*, *Chusenella brevipola golshanii*, n. subsp., *Parafusulina* (*Skinnerella*) *tarazi*, n. sp., *P.* (*S.*) *zagrosensis*, n. sp., *Verbeekina verbeeki*, *Neoschwagerina cheni*, *Afghanella schencki*, etc. The appearance of *N. cheni* marks this interval and this part is called the *Neoschwagerina cheni* zone.

Succeeding strata (Hor. R0 to Hor. R15), about 120 m thick, contain similar fusulinid fauna to that of the *cheni* Zone, but can be distinguished by the appearance of more advanced species of *Neoschwagerina*, such as *N. margaritae* and *N. pinguis*, and is separated as the *N. margaritae* Zone.

Smaller foraminifers are a subordinate element, constituted by rather simple forms belonging to eight genera, such as *Glomospira, Palaeotextularia, Climacammina, Endothyra, Pachyphloia,* etc. Colonial corals and algae are found at several horizons. They are *Yatsengia hangchowensis, Waagenophyllum kueichowensis, Ipciphyllum laosense, Sinopora asiatica, Michelinia favositoides* and algae, *Mizzia* sp.

Brachiopods are rare excepting in the uppermost brachiopod beds. From *N. cheni* Zone only one species, *Phricodothyris asiatica* could be identified (Hor. N8–9). *Edriosteges poyangensis* and *Edriosteges* sp. A occur in the lower part of the *N. margaritae* Zone (Hor. R2). The brachiopod beds (Hor. R18 to R21) yield abundant shells which belong to twenty-four species. Among them, *Krotovia jisuensiformis, Orthotichia avushensis, Meekella arakeljani, Phricodothyris indicus, Spinomarginifera spinosocostata,* and *Edriosteges poyangensis* are important.

It is noteworthy that an ammonite *Xenodiscus muratai* BANDO (1979) has been obtained from the top of the unit.

Hambast Valley section (Fig. 6)

The lowermost part of Unit 1 (Hor. M3 to Hor. M1), about 25 m thick, contains *Schwagerina quasifusuliniformis, Yangchienia* sp., *Staffella* sp. and *Nankinella* spp. and is designated as the *Schwagerna quasifusuliniformis* Zone. The overlying strata (Hor. K0 to Hor. K20), about 70 m thick, are marked by the association of *Eopolydiexodina douglasi, E. bandoi,* n. sp., *Parafusulina (Skinnerella) zagrosensis,* n. sp., *Verbeekina verbeeki, Rugososchwagerina?* sp. and *Afghanella schencki.* This assemblage is quite identical with that of the *E. douglasi* Zone at Surmaq area and the *Schwagerina quasifusuliniformis* Zone may be present below the measured part of the Surmaq section.

The interval from Hor. K21 to Hor. K37, about 95 m thick, is represented by *Chusenella iranensis,* n. sp., *Verbeekina verbeeki, Neoschwagerina* sp., *Afghanella schencki* and *Parafusulina pseudopadangensis,* n. sp. No diagnostic neoschwagerinid could be obtained, but this part is correlated with the *N. cheni* Zone at Surmaq because it is located between the *E. douglasi* Zone, below, and the *N. margaritae* Zone, above.

The Upper part of the unit, about 175 m thick, can be referred to as the *N. margaritae* Zone because of the occurrence of the named species in association with *Chusenella brevipola golshanii,* n. subsp., *Verbeekina verbeeki,* and *Parafusulina pseudopadangensis,* n. sp.

Smaller foraminifers are found throughout the unit. Important species are *Globivalvulina vonderschmitti, G. cyprica* and *Lunucammina postcarbonica,* all of which are, however, rather long-ranging.

Brachiopod fossils have been collected from four horizons, among which the highest one is most fossiliferous and may be called the brachiopod beds. Twenty-four species could be identified altogether, among which four species are found from the lowermost horizon (Hor. K0), that is, *Ogbinia dzhagrensis, Neochonetes armenicus,*

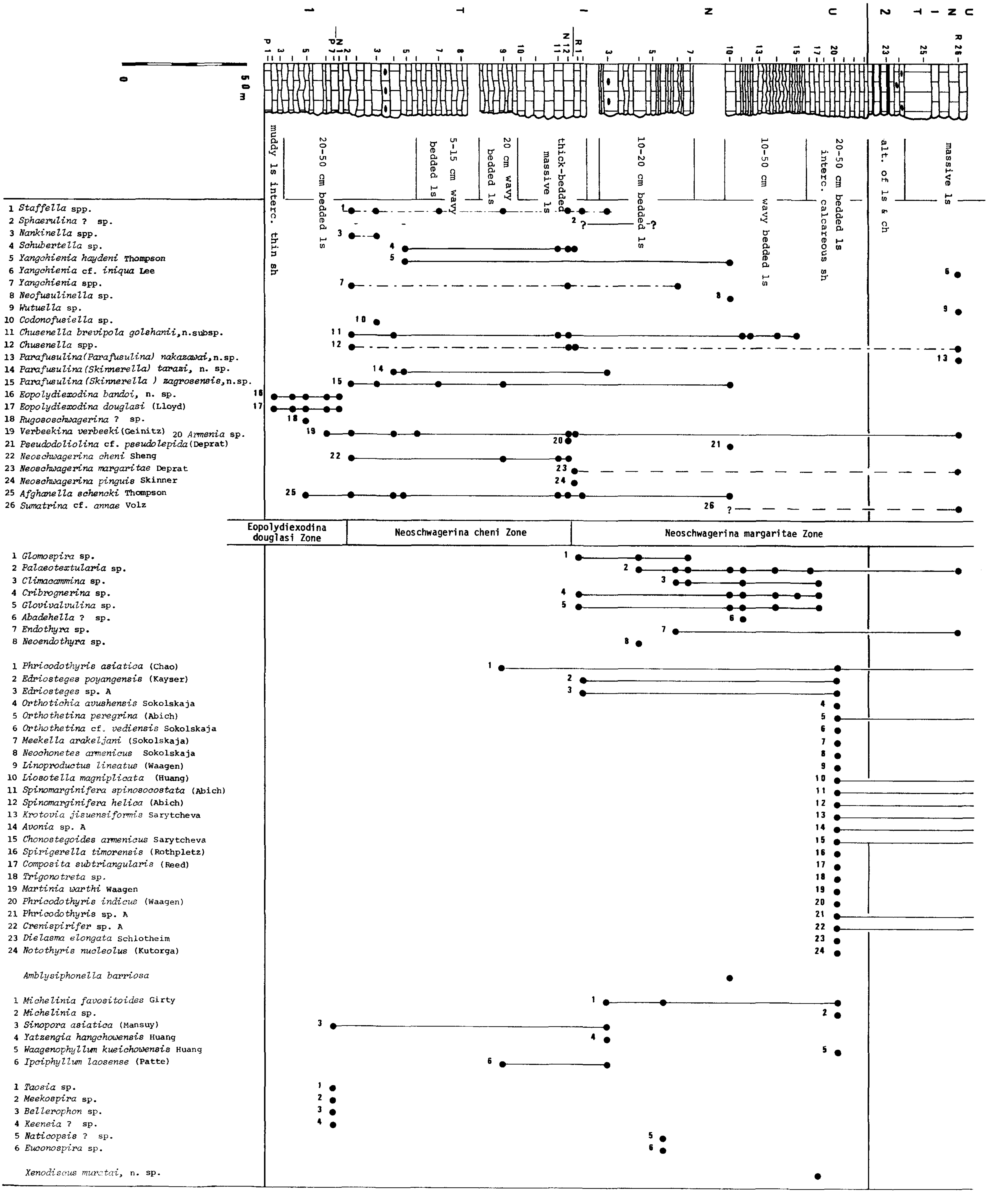

Fig. 5a. Columnar section and range-chart of fossils of Units 1 and 2, Section NR (Surmaq).

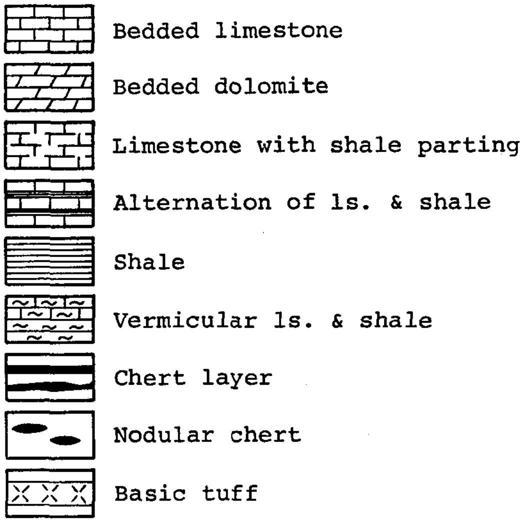

Fig. 5b. Legend of Figs. 5–9, 10, and 12–14.

Phricodothyris asiatica and *Krotovia jisuensiformis*. The brachiopod beds (Hor K62 to Hor. K65) are compared to the brachiopod beds of Surmaq section, both occupying the uppermost part of Unit 1, but those of Hambast Valley are less in number of species and more in number of individuals. Among nineteen species eleven species are common to the Surmaq section.

Corals identified in the field as *Wentzelella, Waagenophyllum* and *Michelinia* occur at several horizons, and two new trilobites named *Iranospidium sagittalis* and *Acropyge lanceolata* by Kobayashi and Hamada (1978) have been obtained from the uppermost horizon (brachiopod beds).

Comparison with other regions

The correlation of Unit 1 with other regions in the Tethys can be made with certainty by fusulinid zones mentioned above. The *Neoschwagerina margaritae* Zone in Abadeh is safely correlated with the named zone which is widely distributed in the Middle and East Tethys, such as Southeast Pamir (Leven, 1967), Southeast Asia (Colani, 1913) and Japan (Toriyama, 1967) (Table 2). *Neoschwagerina cheni* is frequently associated with *N. craticulifera* in other regions, and the *N. cheni* Zone in Abadeh is compared to the *N. craticulifera* Zone in other part of the Tethys stratigraphically as well as paleontologically. *Eopolydiexodina* and *Orientoschwagerina* are characteristic genera in the West Tethys. The Abadeh succession offers important data for their biostratigraphic position. The *Eopolydiexodina douglasi* Zone is now confirmed to be overlain by the *N. cheni* Zone in Abadeh region. Furthermore, *Afghanella schencki* is found along with *Eopolydiexodina*. The genus *Afghanella* is widely distributed throughout the Tethyan realm. It is limited in biostratigraphic distribution to the "*Neoschwagerina* Zone", especially its lower part, that is, the *N. simplex* Zone and the *N. craticulifera* Zone, but has not been reported from either *Misellina* Zone or *Parafusulina* Zone. Therefore, it is certainly concluded that the *E. douglasi* Zone is correlated with the *N. simplex* Zone in Pamir and Japan and the lower Maokouan *Cancellina* Subzone in South China.

Schwagerina quasifusuliniformis was described from the Kubergandinian (*Cancellina* Zone) in Pamir by LEVEN (1967), and the *S. quasifusuliniformis* Zone can also be included in the *Cencellina* Zone of Pamir and other regions.

According to TARAZ (1974), Unit 1 contains *Schubertella* sp., *Chusenella* sp. and *Pseudoschwagerina* sp. (identified by F. BOZORNIA) in a layer 10 m above the base and *Schwagerina* sp., *Chusenella* sp., *Rauserella* sp. and *Schubertella* sp. 20 m above the base. The presence of *Chusenella* suggests the basal part to be younger than the *Pseudoschwagerina* Zone.

Our materials collected from the same horizon are identified as *Cuniculinella* aff. *rotunda, C.* aff. *turgida, C.* n. sp., *Schwagerina* sp. and *Darvasites* cf. *ordinatus. D. ordinatus* ranges from the Artinskian *Pseudofusulina* Zone to the lower *Misellina* Zone. *Cuniculinella* assemblage occurs from the Middle and Upper Wolfcampian of North America. The association of *Darvasites* and *Cuniculinella* suggests the correlation of this part with the *Darvasites-Chalaroschwagerina* horizon of Transcaucasia and Afghanistan and *Pseudofusulina* Zone* of KANMERA *et al.* (1976) rather than *Misellina* Zone.

The brachiopod fauna of Unit 1 is intimately related to that of the Gnishik and Khachik beds in Transcaucasia in having twenty-one species in common among thirty-four identified species. Of these fossils, eight species (*Phricodothyris asiatica, Edriosteges poyangensis, Vediproductus vediensis, Phricodothyris indicus, Dielasma elongata, Linoproductus lineatus, Chonostegoides armenicus* and *Notothyris nucleolus*) are limited to the Gnishik, seven species (*Orthotichia avushensis, Liosotella magniplicata, Krotovia jisuensiformis, Composita subtriangularis, Ogbinia dzhagrensis, Richthofenia lawrenciana* and *Orthothetina vediensis*) occur throughout the Gnishik and Khachik, one species (*Meekella arakeljani*) is confined to the Khachik, three species (*Spinomarginifera spinosocostata, Spinomarginifera helica* and *Orthothetina peregrina*) are Dzhulfian (Baisalian), and two species (*Neochonetes armenicus* and *Wellerella arthaberi*) range from the Gnishik to Dzhulfa beds.

Judging from the occurrences of the brachiopods, the interval from *E. douglasi* Zone to *N. margaritae* Zone is correlated with the Gnishik beds in Transcaucasia. This conclusion accords with that deduced from fusulinid zonation, because the

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* This *Pseudofusulina* may be referred to *Chalaroschwagerina* of SKINNER and WILDE (1965).

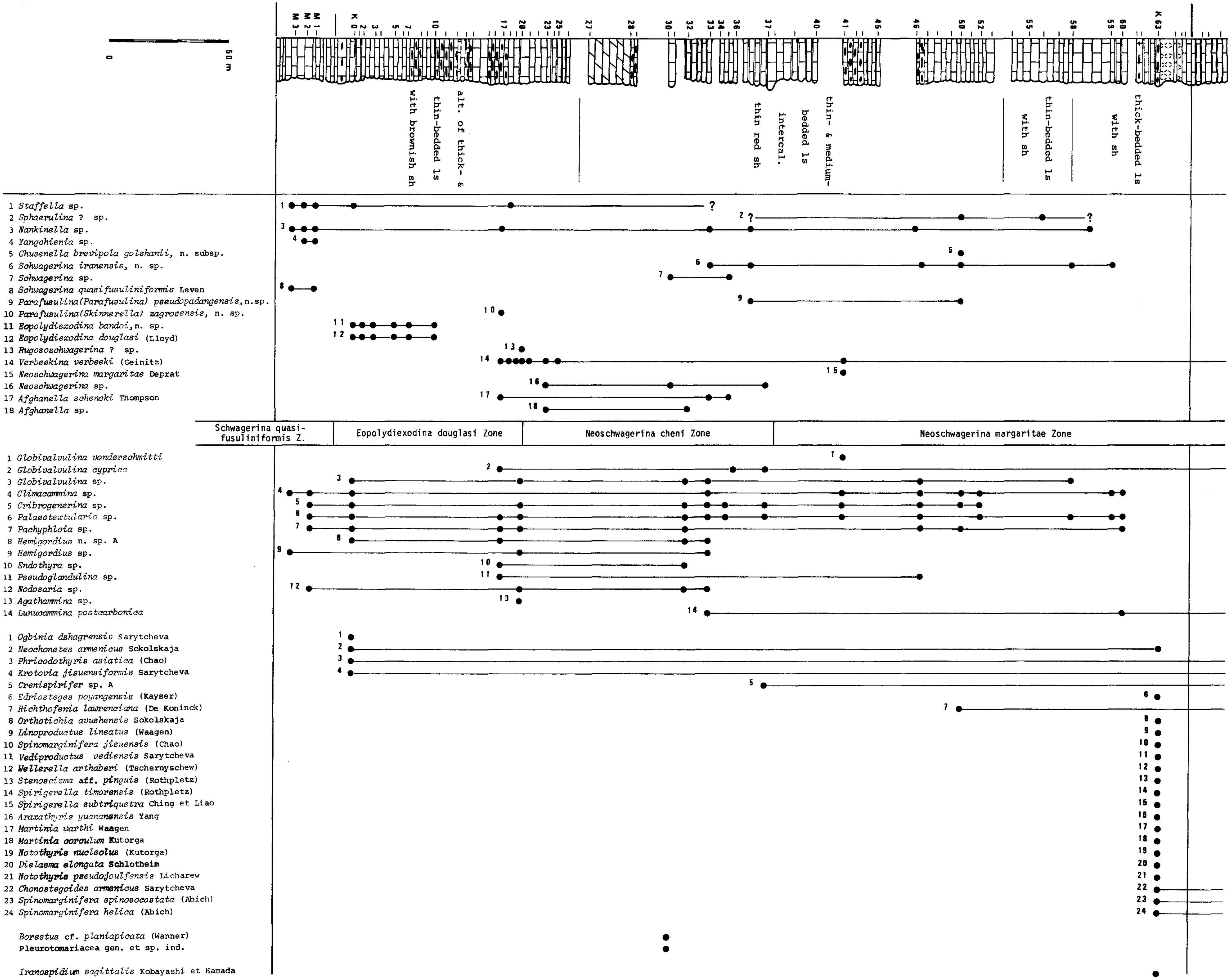


Fig. 6. Columnar section and range-chart of fossils of Unit 1, Section MK (Hambast Valley).

Gnishik beds are characterized by the association of *Eopolydiexodina, Verbeekina* and *Pseudodoliolina* which is allied to the fauna of Unit 1 (LEVEN, 1975a). The corals taken from the *E. douglasi* Zone to the *N. margaritae* zone are related to those of the upper Chihsia and lower Maokou beds (*Misellina* zone to *Neoschwagerina* zone).

The occurrence of *Xenodiscus* from the uppermost part of Unit 1 is important, because the genus is limited to the late Permian so far. However, the Abadeh species, named *X. muratai* BANDO is more primitive than any other known species of the genus (BANDO, 1979).

2. **Unit 2** (Figs. 5 and 7)

Unit 2, about 80 m thick, consists of alternations of limestone, dolomitic limestone and chert. It is very poor in organic remains and no megafossils excepting crinoid fragments could be obtained. In the Surmaq section fusulinid fossils were detected from a layer about 32 m above the base (Hor. R26). They are identified as *Yangchienia haydeni, Wutuella* sp., *Schwagerina* sp., *Parafusulina* (*Parafusulina*) *nakazawai*, n. sp., *Verbeekina verbeeki* and *Neoschwagerina margaritae*. From the top of this unit at Hambast Valley *Chusenella* sp. and *Reichelina* sp. could be detected. In a previous paper (NAKAZAWA & KAPOOR, 1977) this unit was included in the *Chusenella* (= *Orientoschwagerina*) *abichi* Zone together with Unit 3, but it is now placed in the *N. margaritae* Zone by the discovery of the named species.

Some smaller foraminifers (*Palaeotextularia* sp. and *Endothyra* sp.) are found in association with fusulinids, and many sponge spicules are contained in chert nodules and bands.

3. **Unit 3** (Fig. 7)

Unit 3, about 75 m thick, consists mostly of bedded limestones and contains various fossils throughout the unit. Smaller foraminifers are diversified in this unit; more than eighteen species are discriminated belonging to *Glomospira, Palaeotextularia, Globivalvulina, Dagmarita, Endothyra, Neoendothyra, Agathammina, Hemigordius, Pachyphloia, Lunucammina, Lingulina,* etc. Of these, only two forms could be specifically determined, namely, *Globivalvulina vonderschmitti* and *Dagmarita chanakchiensis*, both of which are long-ranging and continue into the overlying units.

The characteristic fusuline fossil is *Orientoschwagerina abichi* which was formerly reported as *Chusenella* sp. (TARAZ, 1974) or *Chusenella abichi* (NAKAZAWA & KAPOOR, 1977). *Verbeekina verbeeki, Dunbarula* aff. *nana, Chusenella* sp., *Schubertella* spp. and primitive forms of *Codonofusiella* also occur.

Unit 3 can be referred to as the *Orientoschwagerina abichi* Zone. This fusulinid zone is located between the *Neoschwagerina margaritae* Zone, below and the *Sphaerulina* sp. Zone, above and most probably correlated with the *Yabeina globosa* Zone or *Lepidolina multiseptata* Zone in Japan and the *Yabeina* Zone in Pamir and South China.

The *O. abichi* Zone is also recognized in the Arpin beds of LEVEN (1975a) and the Gnishik beds of RUZHENTSEV and SARYCHEVA (1965) in Transcaucasia. The Arpin beds which were placed between the Gnishik and the Khachik beds by LEVEN are included in the Gnishik in one place and in the Khachik in another place (person. comm., LEVEN, 1976).

Brachiopod fossils have been collected from four horizons of Section L (Hambast Valley), that is, Hors. L58, L78, L85–95, and L110, each 5 m, 22 m, 43 m to 53 m above the base, and the top of the unit, repectively. The following nine species can be identified; *Crenispirifer* sp. A, *Richthofenia lawrenciana, Phricodothyris* sp. A, *Chonostegoides armenicus, Leptodus* sp. A, *Orthothetina iljinae, Spinomarginifera helica, Cryptospirifer iranica,* n. sp. and *Martiniopsis* sp.

Spinomarginifera helica is a Dzhulfian species in Armenia but occurs in the Ruteh and Nesen Formations in the Central Alborz Mountains (SESTINI, 1965; SESTINI & GLAUS, 1966). *Orthothetina iljinae* and *Richthofenia lawrenciana* range from the Gnishik to the Khachik. On the other hand, *Chonostegoides armenicus* is limited to the Gnishik beds, and *Cryptospirifer iranica* is discovered from the Gnishik equivalent in Iranian Julfa (unpublished data) and from the Upper Permian in Sainbeyli of Turkey which is correlated with the Gnishik beds based on bryozoans (SAKAGAMI, 1976). Accordingly, Unit 3 can be correlated with the Gnishik beds (s.l.) or the Arpin beds of LEVEN in Transcaucasia as was concluded from fusulinids.

In addition to these fossils, *Ipciphyllum simplex, I. flexiosum* and *Wentzelellites* or *Lonsdaleiastraea* sp., *Bellerophon* sp. and pleurotomarian gastropods were found in this unit. The two *Ipciphyllum* species stated above occur in the upper part of the Maokou Limestone (the *Neoschwagerina* Zone to the *Yabeina* Zone) in China. A bryozoan species, *Hexagonella tortuosa* was originally described from the Middle Productus Limestone in the Salt Range region, Pakistan.

4. **Unit 4** (Fig. 7)

As stated in the previous chapter, Unit 4 in this paper includes the upper part of Unit 3 of TARAZ (1974), which is treated as Unit 4a in the present paper.

Smaller foraminifers of Unit 4a does not essentially differ from those of Unit 3. The overlying Unit 4b is characterized by more diversified assemblage, which is constituted by more than 46 species belonging to 25 genera. Main species are, *Abadehella tarazi, A. biconvexa, A. coniformis, Robuloides lens, Eocrystellaria typica, Neoendothyra parva, Discospirella plana, D. minima, Baisalina pulchra, Hemigordius renzi, Agathammina ovata, Nodosaria shikhanica, Lingulina elegantula,* etc.

Thus, the formainiferal assemblage of Unit 4 shows an intermediate character between the Khachik and the Dzhulfian faunas of Transcaucasia. It also corresponds to phase II of REITLINGER (1965) represented by the Khachik fauna, and it has some alliance to the Pamirian fauna of the Kalabelsk beds (LEVEN, 1967). A noticeable

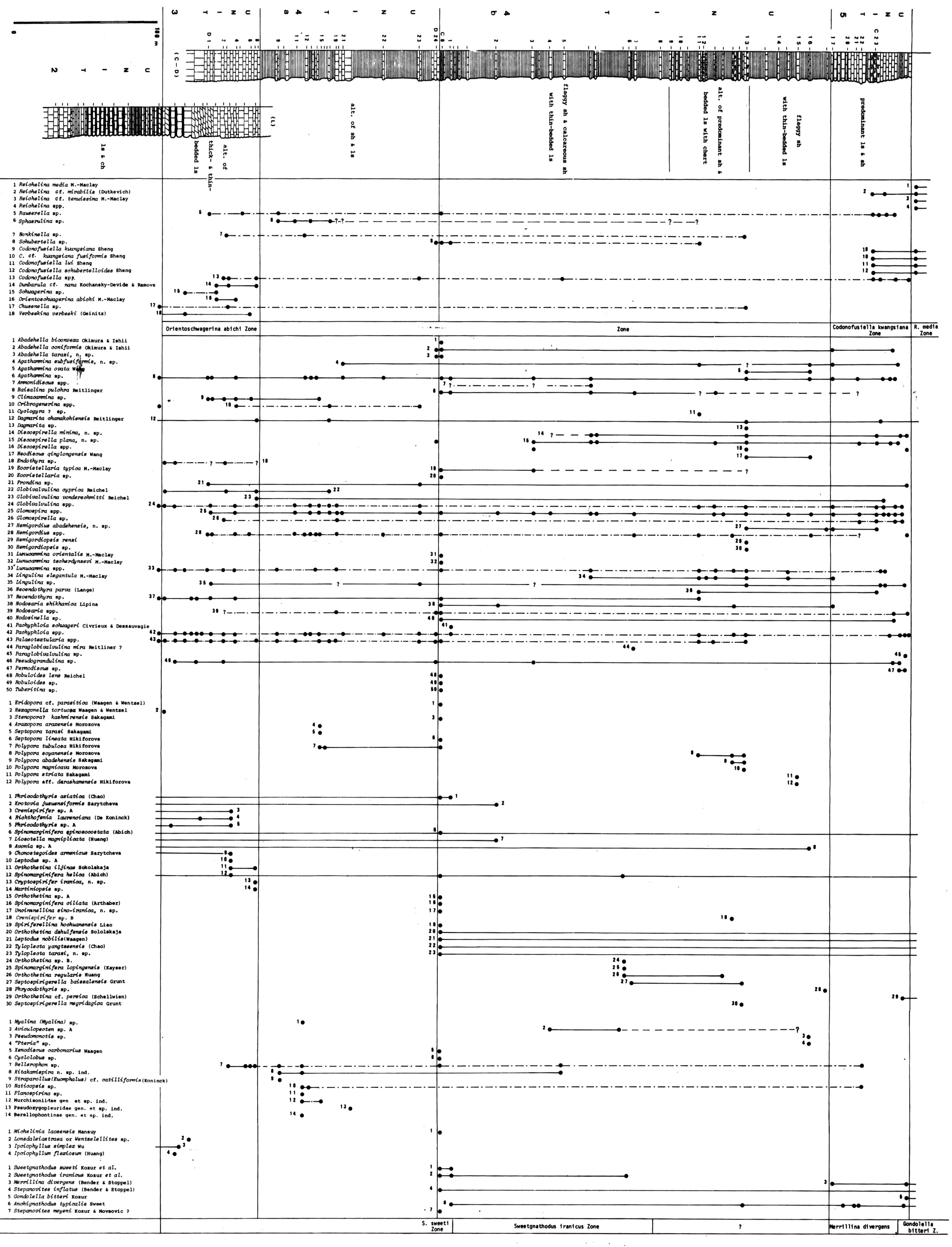


Fig. 7. Columnar section and range-chart of fossils of Units 2-5. Units 2 and 3, Section L and Units 3-5, Section C-D.

fact is that the genus *Abadehella* has a rather limited vertical but wide geographical distribution. It occurs in the lowermost member of the Zewan Formation in Kashmir, the *Palaeofusulina* limestone in Malaysia, the *Lepidolina multiseptata* limestone in Cambodia and Japan, and the *Lepidolina kumaensis* Zone or its equivalent in Japan (OKIMURA *et al.*, 1975).

Comparing with the predominance of smaller foraminifers, fusulinids are rather poor, represented by small forms which belong to *Sphaerulina, Schubertella* and *Codonofusiella*. The only exception is a relict species of *Chusenella* discovered in a layer about 60 m below the top of the unit (Hor. C13). Unit 4 as a whole is included in the *Sphaerulina* sp. Zone. There are no diagnostic fusulinids, but the disappearance of larger fusulinids belonging to Verbeekinidae is characteristic. This zone may be stratigraphically correlated with the *Lepidolina kumaensis* Zone and the lower part of the *Codonofusiella-Reichelina* Zone in Japan and a part of the Wujapingian *Codonofusiella* Zone in South China.

Brachiopod fossils are found in nine horizons of Unit 4b. Only the lowermost horizon (Hor. C0) has a rich fauna, and others are rare in numbers of species and individuals. Among twenty-one discriminated species, six (*Phricodothyris asiatica, Krotovia jisuensiformis, Spinomarginifera spinosocostata, Liosotella magniplicata, Avonia* sp. A and *Spinomarginifera helica*) continue from the preceding units; six species (*Spinomarginifera spinosocostata, S. helica, Orthothetina dzhulfensis, Leptodus nobilis, Tyloplecta yangtzeensis* and *T. tarazi,* n. sp.) range into the Dzhulfian Unit 6, and the remaining eleven species (*Spiriferellina hochuanensis, Orthothetina regularis, Spinomarginifera lopingensis,* etc.) are confined to this unit.

Consequently, the brachiopod fauna shows an intermediate nature between the underlying and the overlying units as in the case of foraminifers. Five species have a range of the Gnishik to Khachik, six species occur in the Dzhulfa beds in Armenia, five species in the Ruteh Formation in Central Alborz and seven in the Nesen Formation. The fauna has several species shared with the Wujaping fauna in South China. Based on the common species of brachiopods, the Unit 4b can reasonably be compared to the Khachik beds in Transcaucasia and a part of the Nesen Formation in Elikah Valley of Alborz Mountains.

Ammonoids are very few, only *Xenodiscus carbonarius* and *Cyclolobus* sp. have been procured from the base of Unit 4b (Hor. C0) (BANDO, 1979). The specimen of *Cyclolobus* is, however, too small being about two centimetres in diameter and weathered, and cannot be specifically determined. *Xenodiscus carbonarius* has been reported from the Kalabagh Member (uppermost Wargal Formation) and the Chhidru Formation in Pakistan, the Zewan Formation in Kashmir, the Kuling Shales and the Chitichum Limestone in the Himalayas and the Amarassi "Formation" in Timor but not found from the Guadalupian in the United States. It suggests a post-Guadalupian age of the unit.

Conodont fossils were mainly examined in Section C. They are rather rare. Only four species have been detected, that is, *Stepanovites inflatus?*, *Sweetgnathodus sweeti*, and *S. iranicus* from the basal part of Unit 4b, *S. iranicus* from the middle horizon of Unit 4b and *Anchignathodus typicalis* (*minutus* of authors) throughout the unit. Although the materials are poor, the lower half of Unit 4b is tentatively assigned to the *Sweetgnathodus iranicus* Zone and the basal part to the *S. sweeti* Zone. This zonation is identical with that of KOZUR *et al.* (1978) in the Abadeh region.

Bryozoans have been collected from Sections C and D. Eleven species belonging to *Eridopora, Stenopora, Araxopora, Septopora* and *Polypora* are distinguished. The lower part of Unit 4 (Unit 4a and the basal part of Unit 4b) contains two Gnishik species, *Septopora lineata* and *Polypora tubulosa*, and one Wargal species, *Eridopora* cf. *parasitica.* The upper part contains two lower Kazanian forms (*Polypora soyanensis* and *P. magnicava*) and one lower Dzhulfian species, *Polypora* aff. *darashamensis.* According to MOROZOVA (1970), the Kazanian of Russian platform can be correlated with the Khachik beds in Armenia. If so, Unit 4 has bryozoans similar to those of the Gnishik in the lower part and of the Khachik in the upper.

Gastropods are common in Unit 4a, which are determined as *Kitakamispira* n. sp., *Straparollus* (*Euomphalus*) cf. *catilloides, Naticopsis* sp., etc. Bivalves are rare; they are *Myalina* (*Myalina*) sp. and an indeterminable large bivalve of Unit 4a, and *Aviculopecten* sp. A, *Pseudomonotis* sp. and "*Pteria*" sp. of Unit 4b.

5. **Unit 5** (Fig. 7)

Unit 5, about 58 m thick, is composed of cliff-making bedded limestones with some chert nodules and scarce in megafossils. Microfossils are represented mainly by small fusulinids and foraminifers and conodonts.

The fusulinid fauna consists of *Reichelina* cf. *mirabilis, Codonofusiella kwangsiana, C.* cf. *kwangsiana, C. schubertelloides, C. lui,* and *Rauserella* sp. and completely lacks larger fusulinids. This unit can be assigned to the *Codonofusiella kwangsiana* Zone.

The fauna is intimately related to the *Codonofusiella* fauna of the Wujaping (Wuchiaping) Stage of South China and the uppermost part of the Arpin beds, and safely correlated to them.

The foraminiferal fauna is similar to that of Unit 4b, but decreases in number of species, consisting of twenty-four species of eighteen genera. Many species flourished in Unit 4 disappeared near the middle of Unit 5, such as *Globivalvulina vonderschmitti, Abadehella coniformis, Hemigordius abadehensis,* n. sp., *Nodosaria shikhanica* and *Lingulina elegantula.* On the other hand, nodosariids, the main element of Unit 6, increase upwards in this unit, and *Discospirella minima* and *D. plana* survived into the overlying strata.

Conodonts could be detected at several horizons, that is, *Merrillina divergens* at the base and the top of the unit, *Gondolella bitteri* at the top (Hor. C17) and

Anchignathodus typicalis throughout the unit.

All three species range into Unit 6, but the main part of Unit 5 can be referred to as the *Merrillina divergens* Zone. The uppermost part is included in the next *Gondolella bitteri* Zone. KOZUR *et al.* (1978) reported the occurrence of *Merrillina divergens* from the middle part of the unit and *Gondolella leveni* from the uppermost part. They referred the main part of Unit 5 to the *G. bitteri* Zone, and the uppermost part to the *G. leveni* Zone, although they could not find *bitteri* in Unit 5. KOZUR (1978) also included Units 4 and 5 together in the *Gondolella bitteri-Merrillina divergens* assemblage zone which according to him characterizes the Abadehian Stage.

6. **Unit 6 and Unit 7** (Fig. 8)

Units 6 and 7 attaining 34–35 m in total thickness represent the uppermost part of the Permian in Abadeh region. This part is marked by a sudden decrease of benthonic organisms, such as brachiopods, corals, bryozoans and benthonic foraminifers. On the contrary, nectobenthonic cephalopods and presumably nectonic conodonts became prolific.

Cephalopods were carefully examined in Sections A, B and C, based on which the range-chart was made. The results have recently been published (BANDO, 1979). The lowermost part of Unit 6, 3 to 4 m thick, is poor in cephalopods, especially in ammonoids. Only one specimen of *Araxoceras latum* was collected near the base, from a float block. This interval comprises many brachiopods referrable to *Araxilevis, Orthothetina, Leptodus,* etc., and is tentatively named the *Araxilevis* beds. Two nautiloids, *Domatoceras* sp. and *Syringonautilus* sp. were obtained from this part.

Ammonoids were suddenly diversified above the *Araxilevis* beds, dominated by araxoceratids, such as *Araxoceras rotoides, A. tectum, A. glenisteri, Vescotoceras evanium, Vedioceras nakamurai,* etc. Unit 6 excepting the *Araxilevis* beds is assigned to the *Araxoceras rotoides* Zone. *Vedioceras nakamurai* is confied to the upper 4 m part of the unit, and the *rotoides* Zone can be subdivided into two subzones, the *Araxoceras tectum* Subzone, below, and the *Vedioceras nakamurai* Subzone, above. Especially interesting is a discovery of *Eoaraxoceras ruzhencevi* from the basal part of the *tectum* Subzone, because this species was previously known only from the La Colorada beds, in Mexico so far and is considered to be an ancestral form of *Araxoceras.* TARAZ (1971, 1974) recorded *Cyclolobus* sp. and *Prototoceras* sp. from the part corresponding to the *tectum* Subzone in this paper. In addition to those ammonoids, *Domatoceras* sp., *Syringonautilus* sp., *Pleuronautilus* sp., and *Foodiceras*? sp. were collected from the *tectum* Subzone and *Dorthoceras* sp., *Neocycloceras* cf. *obliquannulatum* and *Lopingoceras*? sp. from the *nakamurai* Subzone.

Unit 7 is clearly distinguished from Unit 6 by the appearance of *Paratirolites* and *Iranites* and the predominance of *Shevyrevites.* Araxoceratid ammonites are very poor. The lower part, about 5 m thick, is relatively poor in ammonoids, represented by *Shevyrevites shevyrevi* and *Shevyrevites* sp. but lacking in *Paratirolites* and *Iranites*. This part is separated from the rest of the unit as the *Shevyrevites* Zone. The middle part, about 8 m thick, contains various ammonoids characterized by the association of *Paratiroltes, Shevyrevites* and *Iranites*. This part may be called the *Shevyrevites-Paratirolites* Zone. *Vedioceras* sp. was once reported from this zone (TARAZ, 1971).

The upper member, about 4 m thick, has various speceis of *Paratirolites* but few other species, and can be distinguished as the *Paratirolites* Zone.

The ammonoid zonation of Unit 7 is a little different from that of BANDO (1979), who treated whole Unit 7 as the *Shevyrevites shevyrevi* Zone and subdivided it into the *S. shevyrevi* Subzone and the overlying *Paratirolites kittli* Subzone. The former subzone roughly corresponds to the *Shevyrevites* Zone and the latter to the *Shevyrevites-Paratirolites* Zone and the *Paratirolites* Zone in the present zonation. It is noteworthy that *Julfotoceras tarazi*, the ancestral form of *Otoceras woodwardi*, is found in the upper two zones of Unit 7.

Detailed conodont sampling was carried out in Sections A, C, H and HN, mostly at 1–2 m interval. The result is shown in the range-chart (Figs. 8 and 22). Four conodont zones can be established in Units 6 and 7, namely, the *Gondolella bitteri* and the *G. leveni* in Unit 6 and the *G. orientalis* and the *Anchignathodus julfensis* in Unit 7. The *G. bitteri* Zone occupying lower 9 m part of Unit 6 is the assemblage zone of *Merrillina divergens, G. bitteri,* and *G. leveni*. The next *leveni* zone is the assemblage zone of *G. leveni* and *G. orientalis* and marked by the disappearance of *bitteri*. The *orientalis* Zone occupies the lower part of Unit 7 and is characterized by the disappearance of *leveni* and the appearance of *Iranognathodus unicostatus*.

The characteristic species of the uppermost conodont zone, the *Anchignathodus julfensis* Zone, are *Gondolella subcarinata* and *Anchignathodus julfensis*. *G. orientalis* is still found in this zone.

Foraminifers including fusulines were examined mainly on the samples taken from Sections C and H. They were rapidly decreased in number within a lower half of Unit 6. The *Codonofusiella-Reichelina* fauna similar to that of Unit 5 is found at four horizons, of which the highest one is about 12 m above the base of the unit in Section H (Hor. H64). All species of *Codonofusiella* continue from the underlying *Codonofusiella kwangsiana* Zone but this part can be discriminated from the latter as the *R. media* Zone by the predominance of *Reichelina,* such as *R. media, R.* cf. *mirabilis,* and *R.* cf. *tenuissima*. The *R. media* Zone covers the *Araxilevis* beds and the *Araxoceras tectum* Subzone of the Dzhulfian.

Thirteen species of smaller foraminifers survived until the horizon about 3.5 m above the base of Unit 6 (Hor. CC6). They are *Glomospira* sp., *Globivalvulina* sp., *Pachyphloia* sp., *Lunucammina* sp., *Nodosaria* sp., etc. Above this horizon they became extremely rare, only small forms were discovered, such as *Nodosaria minuta,* n. sp., *Glomospirella shengi* and *Pachyphloia* sp., all of which extended into Unit 7.

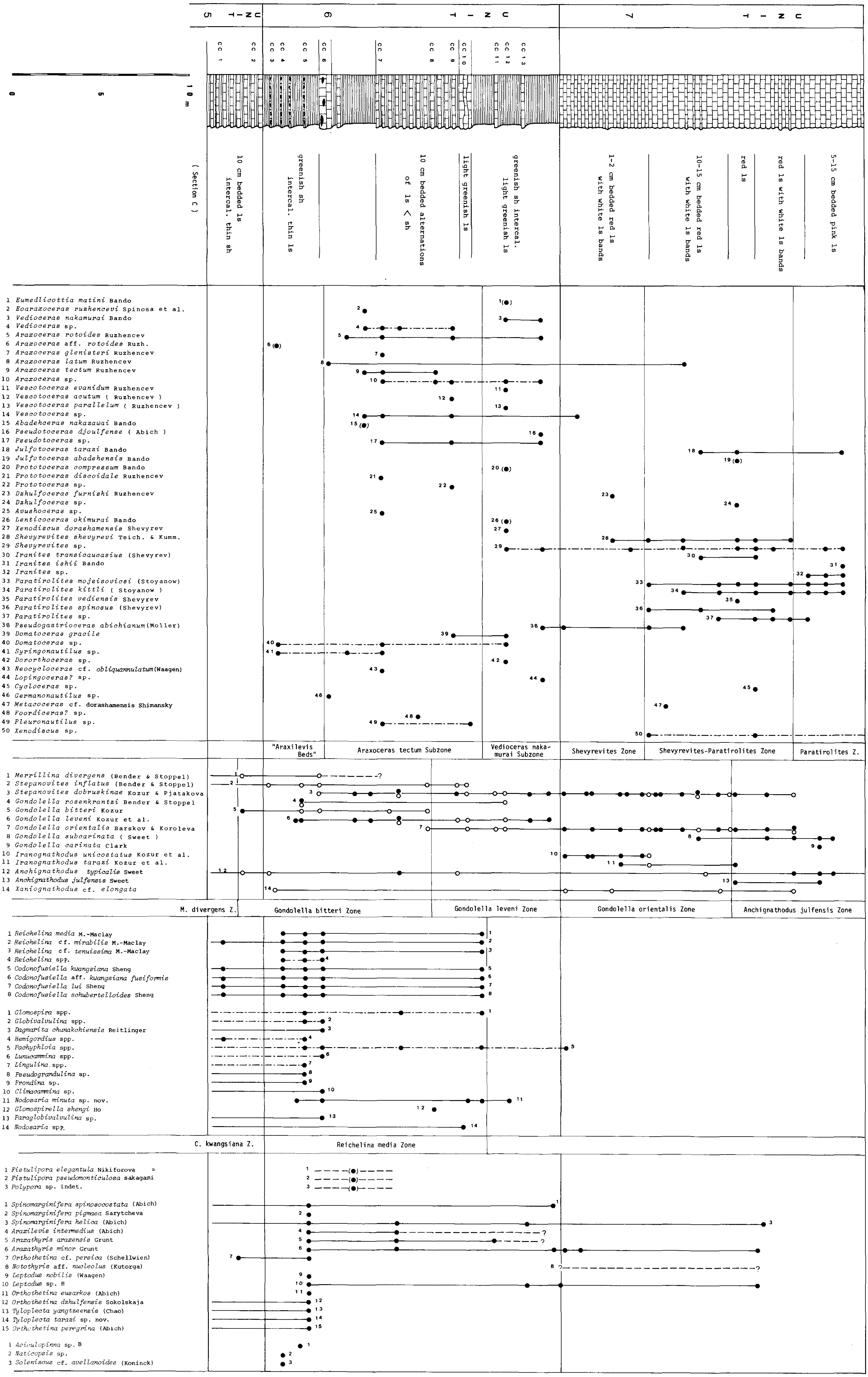


Fig. 8. Columnar section and range-chart of fossils of the Hambast Formation (Units 6 and 7), Section C. Open circles are of Section C and solid circles are of Section A in the range-chart of conodont.

Brachiopods also show a tendency of vertical distribution similar to foraminifers. Thirteen species of brachiopods are identified in the *Araxilevis* beds; *Araxilevis intermedius, Orthothetina* cf. *persica, O. peregrina, O. dzhulfensis, Spinomarginifera spinosocostata, Tyloplecta yangtzeensis, Leptodus* sp. and others.

The number of species decreases to five in the next horizon of the *Araxoceras tectum* Subzone, and in Unit 7 only four species (*Spinomarginifera helica, Araxathyris araxensis minor, Notothyris* aff. *nucleolus* and *Leptodus* sp.) could be found.

No brachiopod fossils were obtained from the *Paratirolites* Zone. Other kinds of fossils are rare. One bivalve species, *Aviculopinna* sp. and two gastropod species, *Naticopsis* sp. and *Soleniscus* cf. *avellanoides* are found in the *Araxilevis* beds. Bryozoans, *Fistulipora elegantula, F. pseudomonticulosa* and *Polypora* aff. *darashamensis* are also limited to the lower part of Unit 6 (SAKAGAMI, 1980).

Corals are represented by a small amount of solitary forms, such as *Pleramplexus* and *Plerophyllum.*

Comparison with the Julfa and Dorasham sections

The fauna of Unit 6 and Unit 7 is closely allied to that of the Dzhulfa (s.s.) beds and the Dorasham beds in Julfa and Dzhulfa, respectively. In the type Dorasham section in Transcaucasia, ammonoids have a very limited vertical distribution, by which, along with brachiopods, the beds are divided into eight units, that is, the *Araxilevis,* the *Araxoceras-Oldhamina,* the *Vedioceras-Haydenella,* the *Phisonites-Comelicania,* the *Tompophiceras* (=*Iranites*), the *Dzhulfites* (=*Paratirolites* according to KUMMEL), the *Bernhardites* (=*Shevyrevites*), and the *Paratirolites* beds (RUZHENTSEV & SARYCHEVA, 1965). But if we examine the occurrence of these fossils in Iranian Julfa region (STEPANOV *et al.*, 1969; TEICHERT *et al.*, 1973), many species are revealed to have a longer stratigraphic range as shown in Fig. 9. Comparing the vertical ranges thus obtained and taking the differences in thickness into consideration as well, the *Araxilevis* beds and the *Paratirolites* Zone in Abadeh region can certainly be correlated with the *Araxilevis* beds and the *Paratirolites* beds in Dorasham section, respectively. The *Shevyrevites-Paratirolites* Zone corresponds to the *Iranites* to the *Shevyrevites* beds. The *Araxoceras tectum* Subzone and the *Vedioceras nakamurai* Subzone are roughly compared to the *Araxoceras-Oldhamina* and the *Vedioceras-Haydenella* beds, respectively, but the exact comparison is difficult due to the absence of *Phisonites* in Abadeh.

Concerning the conodonts, KOZUR *et al.* (1978) recognized three zones in Units 6 and 7, namely, the *Gondolella leveni,* the *G. orientalis,* and the *G. subcarinata,* in ascending order. They referred Unit 5 as the *G. bitteri* Zone comparing with the Transcaucasian conodont zones, although they could not find *bitteri* from Abadeh section. This conodont succession is same as ours, but the zonal boundaries are not the same. Based on their own zonation KOZUR *et al.* correlated only the upper part of Unit 7

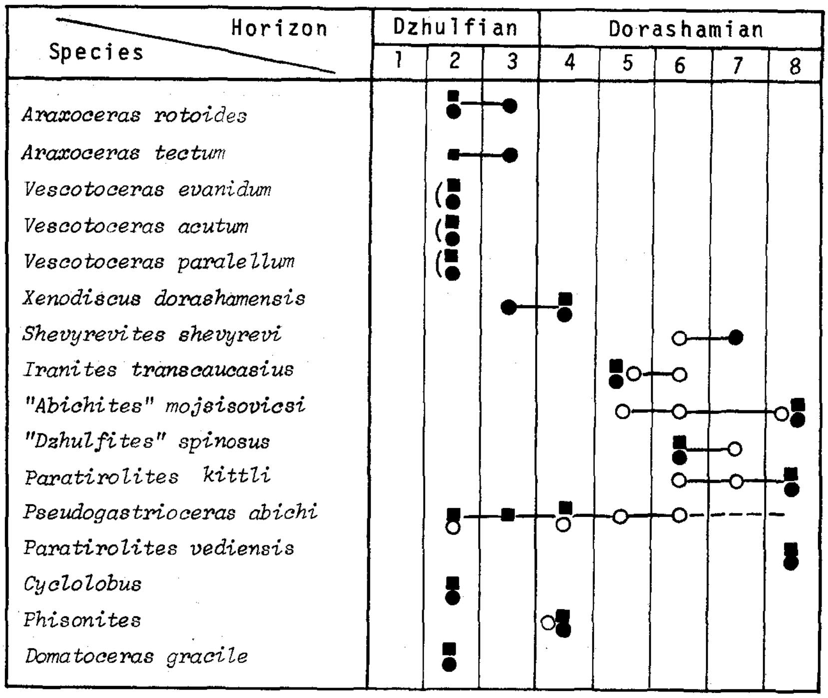


Fig. 9. Stratigraphic occurrence of cephalopod species common to Armenia and Iranian Julfa. Data based on RUZHENTSEV and SARYCHEVA 1965 (solid square), STEPANOV *et al.*, 1969 (solid circle), and TEICHERT *et al.*, 1973 (open circle). 1: *Araxilevis* beds of Armenia or *Araxilevis-Orthotetina* Zone of Julfa, 2: *Araxoceras-Oldhamina* beds or *Pseudogastrioceras-Permophrycodothyris* Zone, 3: *Vedioceras-Haydenella* beds or *Haydenella-Pseudowellerella* Zone, 4: *Phisonites-Comelicania* beds or *Phisonites* Zone, 5: *Tompophiceras* beds or *Tompophiceras* (=*Iranites*) Zone, 6: *Dzhulfites* beds or *Dzhulfites* Zone, 7: *Shevyrevites* beds or *Shevyrevites* Zone, 8: *Paratirolites* beds or *Paratirolites* Zone.

with the Dorashamian beds and the rest with the Dzhulfa beds (the *Araxilevis* beds to the *Vedioceras* beds) in Dorasham section. This interpretation is different from our conclusion based on ammonoid and brachiopod occurrences (Table 2). According to our investigation, *G. orientalis* appears in the uppermost part of the *Vedioceras nakamurai* Subzone. On the other hand, it first appears in the middle part of the *Araxoceras* beds in Dzhulfa. Such discrepancies of ammonoid and conodont zones between the two regions should be further examined in future. The correlation by means of ammonoids and brachiopods is here preferred.

In conclusion, Unit 6 and Unit 7 in Abadeh roughly correspond to the Dzhulfa beds and the Dorasham beds, respectively, but the Unit 6/7 boundary is possibly located a little below the Dzhulfa/Dorasham boundary, that is, *Vedioceras-Haydenella*/

Phisonites-Comelicania boundary.

7. **Unit a (Lower Triassic)** (Fig. 10)

The lowermost part of Unit a, 15–25 m thick, was measured and examined along Sections A, B, C, H and I. The fossils are represented almost exclusively by ammonoids, bivalves, and conodonts accompanied by algae, ostracods, and trace fossils.

Unit a begins with weathered soft, greenish or yellowish grey, partly pinkish-grey shales of 10 to 30 cm in thickness. This is succeeded by stromatolitic limestone beds, 130–180 cm thick. Main part of the unit consists of dark to light grey, thin-bedded limestones and greenish shales. It contains biogenic burrows at many horizons mostly arranged parallel to the bedding plane, and is called the vermicular limestone (TARAZ, 1974).

In the stromatolite beds *Xenodiscus* sp., *Claraia* sp. of *dalpiazi* type and ostracods are found. *Xenodiscus* and/or ophiceratid ammonoids occur in various horizons, that is, 3 m, 12 m, 13 m, 14 m, and 16 m above the base in Section H, 7 m, 9 m and 10 m in Section B, and 8 m above the base in Section C. Most of them are, however, badly preserved and difficult to identify. *Vishnuites pralambha, Ophiceras* (*Lytophiceras*) *dubium, Acanthophiceras golshanii* and *Ophiceras* sp. were collected from a horizon about 9.5 m above the base of the unit in Section C (BANDO, 1979).

The genus *Claraia* is common throughout the examined part. Compilation of the occurrence in various sections shows that *Claraia radialis julfensis* appears at a horizon 3 m above the base and found until 21.5 m, *C. extrema extrema* ranges from 5 m to 17.5 m and *C.* aff. *dalpiazi* from 4 m to 14 m above the base. On the other hand, *C. aurita* first appears a little higher than other claraias, having an interval from 8.3 m to 25 m or more above the base (NAKAZAWA, 1977). Consequently, the lower part of Unit a is divisible into two *Claraia* zones, the *C. radialis julfensis* Zone, below, and the *C. aurita* Zone, above.

Conodonts are common throughout. Three conodont zones can be established founded on the range-chart of Sections A, C and H. The stromatolite beds are characterized by the association of *Anchignathodus typicalis* and *A. parvus*. This part is assigned to the *A. parvus* Zone. The next 10 m part contains *A. parvus, A. turgidus,* and *Isarcicella isarcica*, and is referred to as the *I. isarcica* Zone. *Neospathodus dieneri* appears at about 17 m above the base, by which the *N. dieneri* Zone can be established. No diagnostic conodonts were obtained from the interval between *isarcica* and *dieneri* Zones. According to KOZUR *et al.* (1978), *I. isarcica* first appears about 7.5 m above the base and ranges to about 11 m, but we found it 2 m above the base. It should be mentioned that *Gondolella orientalis* and *G. subcarinata* have been procured at a horizon about 3 m above the base in Section H, because these speceis are confined to the Dorashamian in other areas. It is not certain, however, whether they are

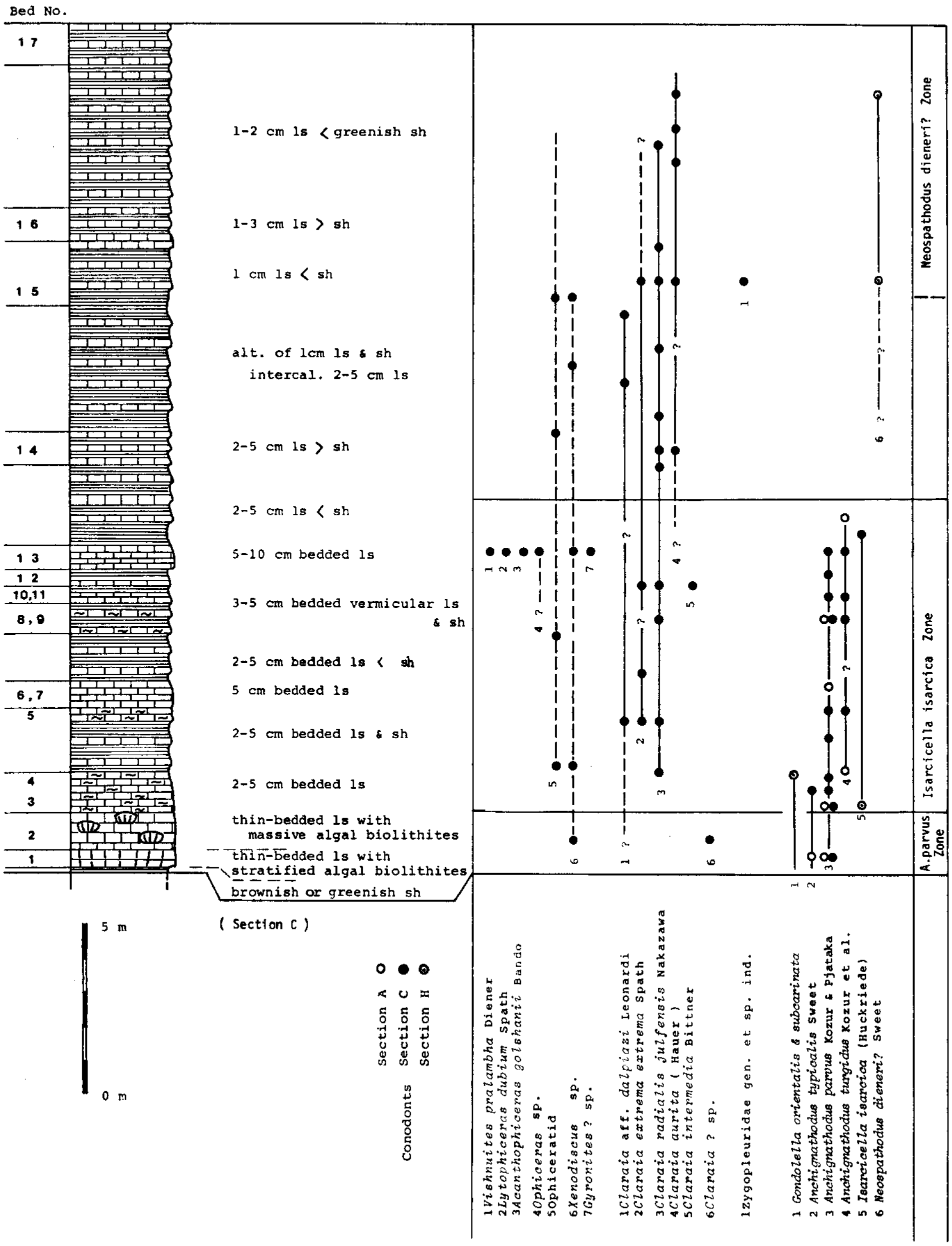


Fig. 10. Columnar section and range-chart of fossils of Unit a, Section C. Range-chart is compiled from various sections.

reowrked.

Bellerophonid gastropods are found from horizons of 1.5 m above the base in Section A, 8.5 m in Section B, and 19 m in Section H.

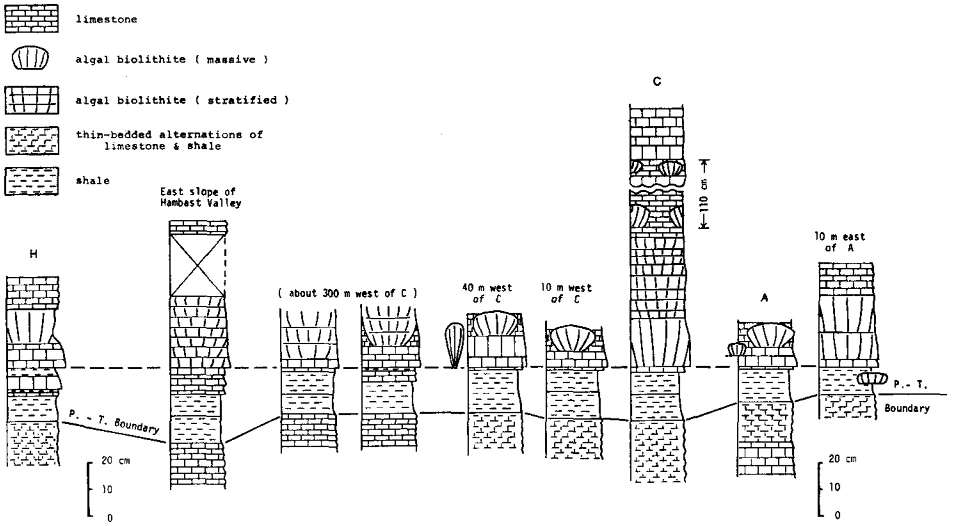


Fig. 11. Detailed columnar sections around the Permian-Triassic boundary.

Comparison with other regions

Among ammonoids, *Lytophiceras dubium* has been reported from the Upper *Vishnuites* beds and the Lower *Proptychites* beds in Greenland (Spath, 1934, 1935) and the *Claraia* beds in Armenia (Rostovtsev & Azaryan, 1973). *Acanthophiceras* is a characteristic ammonite of the *Vishnuites* beds, especially the lower and the middle parts. Some species of *Lytophiceras* such as *L. sakuntala, L.* aff. *kilensis* and *L. russkiense,* are described by Kiparisova (1961) from the *Proptychites* Zone of the Maritime Province of Far East U.S.S.R. In general, the *Lytophiceras* is predominant in the later stage of the *Ophiceras* range zone and associates with *Proptychites* and *Vishunites* in Greenland, Himalayas and Siberia.

Vishnuites pralambha was originally described from the upper part of the *Otoceras* beds in Painkhanda by Diener (1897), but Spath (1930, 34, 35) reported many species of *Vishnuites* from the *Vishnuites* beds in Greenland, which are situated between the *Ophiceras* beds and the *Proptychites* beds. He considered that the *Vishnuites* beds indicate the lower part of the Gyronitan ammonite stage.

Therefore, the *Vishnuites-Lytophiceras-Acanthophiceras* horizon of Unit a is safely correlated with the *Vishnuites* beds of East Greenland, the *Pachyproptychites strigatus* Zone (Upper Griesbachian) in Arctic Canada (Tozer, 1967) and a part of the Upper

Ophiceras to *Vishnuites* beds in Kashmir (NAKAZAWA *et al.*, 1975a), and the *Ophiceras-Vishnuites* beds in Transcaucasia (ROSTOVTSEV & AZARYAN, 1973).

Comparing the conodont zones in Kashmir (NAKAZAWA *et al.*, 1980) where the Zones of *Anchignathodus typicalis, A. parvus, Isarcicella isarcica, Gondolella carinata, Neospathodus kummeli,* and *N. dieneri* are confirmed in ascending order in the interval from the *Otoceras woodwardi* Zone to the *Ophiceras* Zone, the *parvus* Zone and the *dieneri* Zone in the two regions are correlated with each other (Table 2). However, the *isarcica* Zone of Abadeh region includes the *Vishnuites-Lytophiceras* Zone in its upper part, which is correlated with the upper *Ophiceras* Zone (*Ophiceras* sp. Subzone) in Kashmir. This part of the Kashmir section includes the upper part of the *carinata* Zone and the *kummeli* Zone as well. The apparent short vertical range of *isarcica* in Kashmir is considered to be a result of its rare occurrence, and elsewhere the *isarcica* range zone is considered to cover the whole *Ophiceras* Zone. The *isarcica* Zone in Abadeh is referred to a time equivalent of the *Ophiceras* Zone in Kashmir, the upper *Ophiceras* and the *Vishnuites* beds in East Greenland, and the *Ophiceras commune* Zone and the *Pachyproptychites strigatus* Zone of Arctic Canada. The *A. parvus* Zone, which corresponds to the stromatolitic beds, most probably represents the upper part of the *Otoceras woodwardi* Zone (Table 2).

VI. Correlation of the Permian in Abadeh with That of the Other Regions in the Tethys Province

Before going to discuss the classification of the Permian, the international correlation will be examined through the biostratigraphy of the Permian in the Abadeh region examined in the preceding chapter.

1. Comparison with the Julfa and Dorasham sections

The Abadeh section is most similar to that of Julfa and Transcaucasia lithologically and paleontologically. Unit 1 to Unit 5 of the Abadeh section is confidently correlated with the Dabaly — Khachik beds by fusulinids, brachiopods, and smaller foraminifers, as shown in Table 3. The *Orientoschwagerina abichi* Zone of Unit 3 has its equivalent in the Arpin beds of Transcaucasia. Unit 4 is equivalent to the main part of the Khachik beds by the association of *Codonofusiella* and *Chusenella* and Unit 5 correlates with the uppermost part of the Khachik beds by the occurrence of *Codonofusiella schubertelloides*, *C. kwangsiana*, etc. and disappearance of larger fusulinids. The correlations are also based on the similarity of brachiopods and foraminifers.

The *Codonofusiella* beds at Dorasham section were included in the Dzhulfa beds by RUZHENTSEV and SARYCHEVA (1965) but were shifted to the Khachik beds by STEPANOV *et al.* (1969). TARAZ (1974) also included the *Codonofusiella* Zone in the Khachik, but postulated a large time-gap before the deposition of the Dzhulfian

Araxilevis beds, thus correlating the *Codonofusiella-Reichelina* beds of Julfa and Dorasham with the basal part of the Abadeh Formation. This opinion cannot now be accepted, because the uppermost part of the Abadeh Formation is represented by the *Codonofusiella kwangsiana* fauna, which is like that of the *Codonofusiella-Reichelina* beds in Julfa and Dorasham.

Table 2. Comparison of ammonoid and conodont zones between Kashmir and Abadeh

<table>
<tr><th colspan="5">Kashmir (India)</th><th colspan="3">Abadeh (Iran)</th></tr>
<tr><td colspan="2" rowspan="2">F</td><td colspan="2">*Paranorites-Vishnuites* Zone</td><td>*Neospathodus cristagalli* Zone</td><td rowspan="6">a</td><td rowspan="2"></td><td rowspan="2">*Neospathodus dieneri* Zone</td></tr>
<tr><td colspan="2">?</td><td>*Neospathodus dieneri* Zone</td></tr>
<tr><td rowspan="5">E</td><td rowspan="3">E3</td><td rowspan="3">*Ophiceras* Zone</td><td rowspan="2">*Ophiceras* sp. Subzone</td><td>*N. kummeli* Zone</td><td rowspan="4">*Vishnuites*, *Lytophiceras*, *Acanthophiceras*</td><td rowspan="3">*Isarcicella isarcica* Zone</td></tr>
<tr><td>*Gondolella carinata* Z.</td></tr>
<tr><td>*Ophiceras tibeticum* Subzone</td><td>*Isarcicella isarcica* Zone</td></tr>
<tr><td rowspan="2">E2</td><td colspan="2" rowspan="2">*Otoceras woodwardi* Zone</td><td>*Anchignathodus parvus* Zone</td><td>*Anchignathodus parvus* Zone</td></tr>
<tr><td>*Anchignathodus typicalis* Zone</td><td colspan="3">Missing?</td></tr>
</table>

A sharp lithological and faunal change at Unit 5/6 boundary favours the opinion that the base of the Dzhulfa beds should be correlated with the base of the *Araxilevis* beds.

It is important for international correlation that the *Codonofusiella-Reichelina* fauna is carried up to the upper boundary of the *Araxoceras tectum* Subzone in Abadeh, while it disappeared already in the *Araxilevis* beds of Transcaucasia. The relations indicate that the extinction of the *Codonofusiella-Reichelina* fauna is not synchronous but diachronous between the two regions, and consequently the disappearance is facies-controled. It also provides a firm ground to correlate the Dzhulfa beds (Unit 6), or at least its main part, with the Wujapingian Stage in South China, which is characterized by araxoceratid ammonoids in the clastic facies and the *Codonofusiella* fauna in the limestone facies.

2. Comparison with the Nesen Valley section of Iran

The Upper Permian strata called the Nesen Formation are known in the Upper Chalus Valley region and the Heraz Valley region. GLAUS (1964, 1965), SESTINI and GLAUS (1966), and STEPANOV *et al.* (1969) referred the age of the upper part of the Nesen Formation to be Dzhulfian on the basis of the close similarity of brachiopod faunas. We made a preliminary field survey on the Upper Nesen Formation and the Lower Triassic Elikah Formation along the Elikah Valley in 1975. These beds were divided into six units, among which Units 1 and 2 belong to the upper part of the Nesen Formation and Units 3 to 6 to the Lower Triassic Elikah Formation.

The range-chart of the collected fossils is given in Fig. 12. Unit 1, more than 35 m thick, consists of alternations of limestone and shale, and Unit 2, about 20 m thick, is represented mostly by limestones with many chert nodules. Foraminifers are common throughout the examined part, but brachiopod fossils were found only in Unit 1. Among twenty-four species belonging to ten genera of brachiopods, eight species (*Orthothetina eusarkos, Tyloplecta yangtzeensis, Spinomarginifera helica, S.* cf. *ciliata, Araxathyris* cf. *araxensis, Haydenella tumida, Leptodus nobilis* and *Orthotichia* cf. *dorashamensis*) are limited to the Dzhulfa beds in Transcaucasia. Only *Phricodothyris asiatica* and *P. indicus* are confined to the Gnishik beds, and *Orthothetina dzhulfensis* ranges from the Khachik to the Dzhulfa beds.

Three identified bivalve species, *Acanthopecten giganteus, Etheripecten? sichuanensis,* and *Guizhoupecten regularis* are all Wujapingian species in South China (NAKAZAWA, in press), and *Gondolella orientalis* has been detected from the middle part of Unit 1.

These fossil evidences seem to support the Dzhulfian or Baisalian age of the upper Nesen Formation. However, *Tyloplecta yangtzeensis, Spinomarginifera helica, S. ciliata,* and *Leptodus nobilis* are now known in the pre-Dzhulfian beds in Abadeh. Species of *Codonofusiella* and *Reichelina* are similar to those of the *C. kwangsiana* Zone of Abadeh Formation (Unit 5) and the *R. media* Zone of lower Hambast Formation (Unit 6). Furthermore there is no Dzhulfian ammonoids that flourished in all three regions — Abadeh, Julfa and Transcaucasia. The diversified foraminiferal assemblage strongly suggests the pre-Dzhulfian age of this part. In this connection, it should be mentioned that Unit 5 of Abadeh is allied to Unit 2 of Nesen in having chert nodules and being barren in megafossils and that the *Araxilevis* beds are very poor in ammonoids. We suspect that the upper part of the Nesen Formation may be correlated with the upper part of the Abadeh Formation and the *Araxilevis* beds in Abadeh region.

The Lower Triassic Elikah Formation begins with dolomitic calclithite and is divisible into four units, Unit 3 to Unit 6 (Fig. 13). Unit 3, about 30 m thick, is composed of dolostones or dolomitic limestones in beds 5–20 cm thick, sometimes parallel-laminated, intercalating with thin shale layers. No megafossils could be

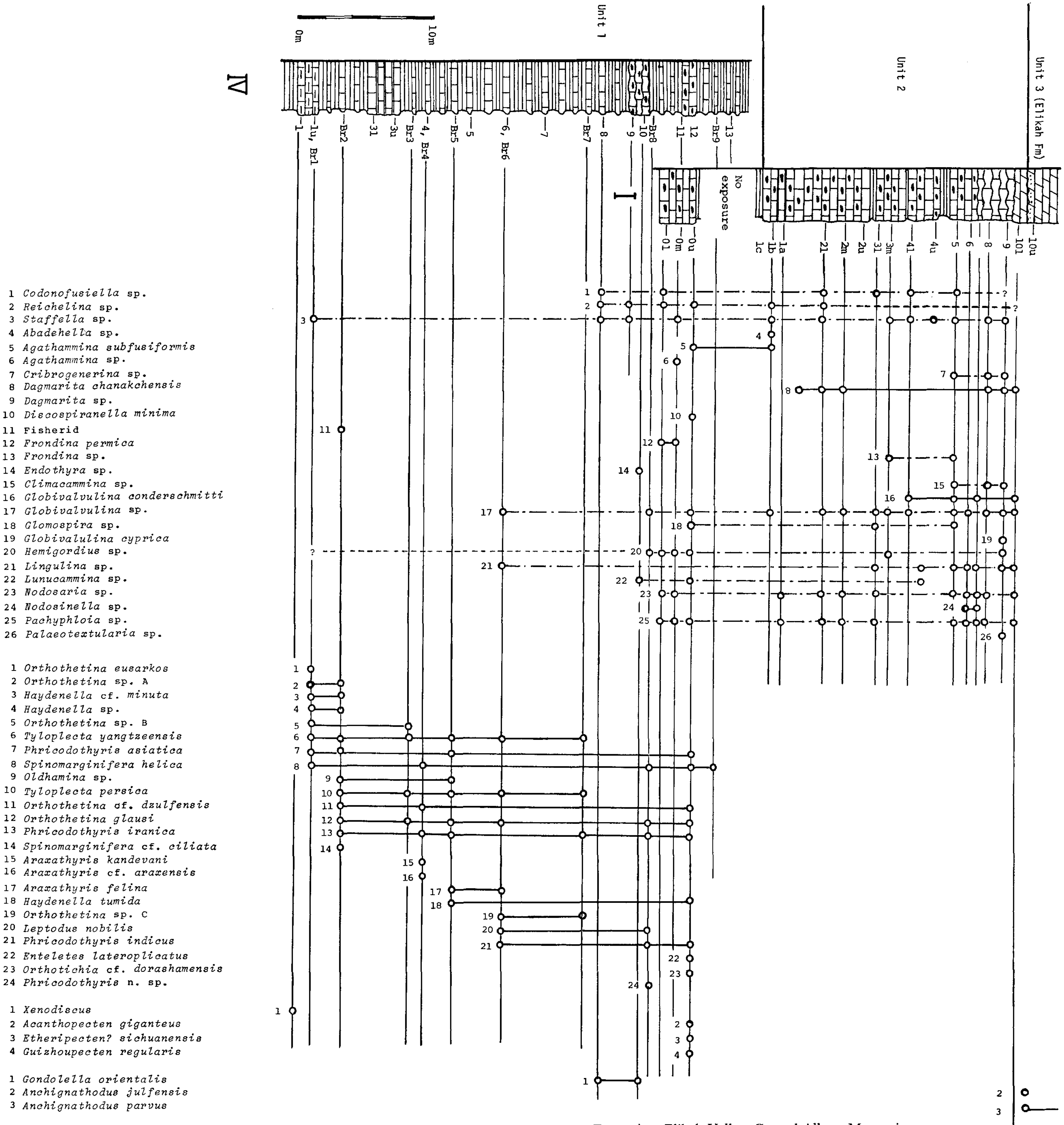


Fig. 12. Columnar section and range-chart of fossils of the Upper Nesen Formation, Elikah Valley, Central Alborz Mountains.

obtained. Two conodont species, *Anchignathodus parvus* and *Isarcicella isarcica*, occur at several horizons, among which *isarcica* is confined to the upper part of the unit.

Unit 4, 3–5 m thick, is alternating dark-grey micritic limestone and oolitic limestone in beds 15–20 cm thick, with *parvus* and *isarcica.*

Unit 5 is about 4 m thick consisting of dark-grey micritic limestones, thin- to medium-bedded. It is similar to the so-called vermicular limestone of the Lower Triassic in Abadeh in having many trace fossils. Main fossils are conodonts represented by *Anchignathodus typicalis, A. turgidus, Neospathodus dieneri* in addition to *parvus* and *isarcica. Gyronites* sp. was discovered at the top of the unit at the Makliz Valley, a tributary of Nesen Valley.

Unit 6, about 34 m thick, is composed of black shales and dark-grey limestones and marly limestones in alternation. Burrows are commonly found in carbonate rocks. This unit bears many bivalves, such as *Claraia* and *Eumorphotis* in the lower part and *Unionites* in association with *Eumorphotis* and *Claraia* in the upper part.

Considering the vertical distribution of conodonts, the lower part of Unit 3 can be assigned to the *Anchignathodus parvus* Zone, the interval from the upper part of Unit 3 to Unit 5 is referred to as the *Isarcicella isarcica* Zone. The lower half of Unit 6 may belong to the *Neospathodus dieneri* Zone. Each conodont zone is considered roughly to correspond to the respective zone in Abadeh region. It is noticeable that the *parvus* Zone in this region being 20 m thick is much thicker than that of Abadeh region, and that the Dorashamian beds and main part of the Dzhulfa beds are lacking beneath the *parvus* Zone.

3. Comparison with the Permian in Pakistan and India

The marine Upper Permian is well developed in the Salt Range and the Trans-Indus Ranges in Pakistan and Kashmir in India; both were examined by Japanese-Pakistani and Japanese-Indian joint research teams.

By the discovery of *Neoschwagerina* cf. *margaritae* from the basal part of the Wargal Formation in the Salt Range (NAKAZAWA & KAPOOR, 1977), this part is certainly correlated with the *margaritae* Zone of the upper part of Unit 1 and Unit 2 in Abadeh and in other parts of the Tethys. The main part of the Wargal, therefore, is now considered to be correlated with the *Yabeina* Zone and younger horizons. This is endorsed by the occurrence of *Colaniella minima, C. nana,* and *C. cylindrica* from the Kalabagh Member (uppermost part of the Wargal Formation) and the lower part of the Chhidru Formation. Those colaniellas usually associated with *Abadehella* in Kashmir (Member A of the Zewan Formation), Japan and Malaysia (ISHII *et al.*, 1975). The genus *Abadehella* was originally described from the base of Unit 4b of the Abadeh Formation, and stratigraphically limited in distribution from the *Lepidolina multiseptata* Zone to the *Palaeofusulina* Zone. *Codonofusiella* and *Reichelina* occur in the middle part of the Wargal which may correspond to the lower part

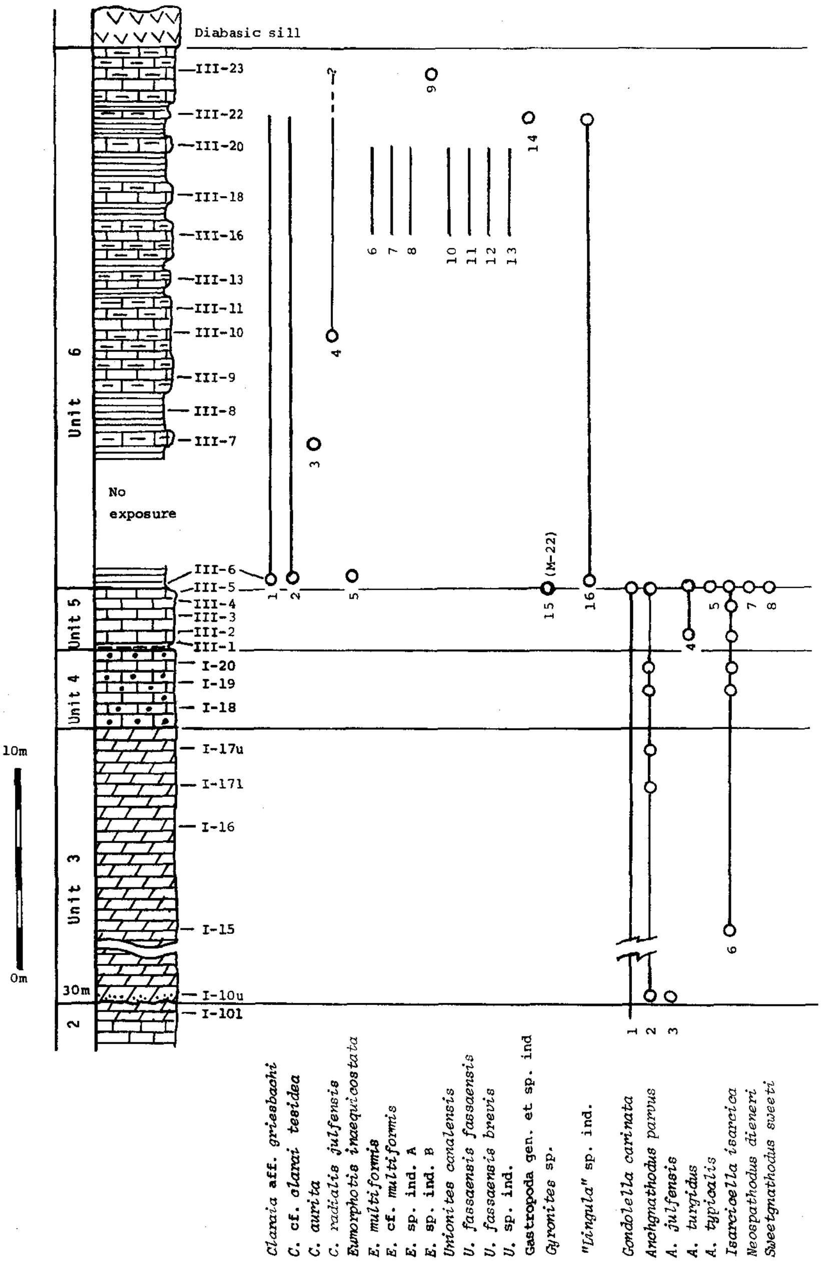


Fig. 13. Columnar section and range-chart of fossils of the Elikah Formation (Lower Triassic), Elikah Valley, Central Alborz Mountains.

of the Abadeh Formation (Unit 4).

The abundant foraminifers of the Kalabagh and the lower Chhidru Formation compare with those of the Abadeh Formation with several species in common, such as *Nodosaria shikhanica, Pachyphloia iranica*, n. sp., *Globivalvulina vonderschmitti* and *Dagmarita chanakchiensis* (unpublished data). The sudden decrease of foraminifers took place between upper and lower Chhidru Formation. Such faunal change may correspond to that happened at Unit 5/6 boundary in Abadeh.

Brachiopods common to both regions are very few. Six common species of Unit 1 contain three Kalabagh species, one Amb, one Amb-Chhidru, and one Kalabagh-Chhidru species. Only one species of Unit 4 is found in Pakistan, namely, Kalabagh-Lower Chhidruan *Leptodus nobilis*. Thus, the accurate correlation based on the brachiopods is difficult, but the Abadeh Formation is possibly correlated with the Kalabagh-Lower Chhidru.

In summary, the Upper Chhidru Formation, the Lower Chhidru-Kalabagh, and the main part of the Wargal Formation are roughly compared to the lower part of Unit 6, the Abadeh Formation (Units 4 and 5), and the upper part of Unit 1 to Unit 3, respectively. But the base of the Abadeh Formation may be located somewhere in the main Wargal Formation.

The comparison with the Kashmir section is not clear because of still fewer species in common. The Upper Permian Zewan Formation in Kashmir is divided into four members (NAKAZAWA *et al.*, 1975a) from A to D. The lowermost unit of the overlying Khunamuh Formation (Unit E_1) was referred to as the latest Permian. The following species are found in both Abadeh and Kashmir.

	ABADEH	KASHMIR
Abadehella coniformis	Unit 4	Member A
Leptodus nobilis	Unit 4 to 6	Member A and B
Xenodiscus carbonarius	Unit 4	Member C
Stenopora? kashmiricus	Unit 4	Member A
Anchignathodus typicalis	Unit 4 to Trias	Member C to Trias
Gondolella carinata	Unit 7	Member C to Trias

Based on these common species, the Abadeh Formation is most probably correlated with Members A and B in Kashmir, but further materials will be required.

4. Comparison with the Permian in South China and Japan

The recent publication on the Upper Permian Cephalopoda in South China by ZHAO *et al.* (1978a) casts serious problems for the correlation and classification of the Permian. They distinguished nine ammonoid zones in the Upper Permian including the unnamed zone of the uppermost horizon as follows.

Stage	(Substage)	Ammonoid zone
Changxing Stage	Upper Substage (Meishan Member)	Unnamed Zone
		Rotodiscoceras Zone
		Pseudotirolites-Pleuronodoceras Zone
	Lower Substage (Baoquing Member)	*Pseudostephanites-Tapashanites* Zone
		Paratirolites-Shevyrevites Zone
		Iranites-Phisonites Zone
Loping Stage	Laoshan Substage	*Sanyangites* Zone
		Araxoceras-Konglingites Zone
		Anderssonoceras-Prototoceras Zone

The Upper Permian in South China is usually collectively called the Loping Series and is divided into the lower, Wujaping (Wuchiaping) Stage and the upper, Changxing (Changhsing) Stage. However, the Loping Stage of the present usage is somewhat different. It includes the Laoshan Formation (upper) and the Loping Formation (lower), but not Changxing Formation. The Wujaping Limestone and the Longtan (Lungtan) Formation belong to the Loping Stage. The Dalong (Talung) Formation represents a clastic rock facies of the Changxing Formation which is composed mainly of limestones.

Incomplete specimens of *Paratirolites*? sp. and *Shevyrevites shevyrevi* were found from the base of the Changxing Formation near Anchun in Guizhou (Kueichow), and ZHAO *et al.* (1978a) concluded the *Paratirolites-Shevyrevites* Zone is below the *Pseudostephanites-Tapashanites* Zone and the Upper Substage of the Changxingian is entirely missing in Transcaucasia, Iran and any other regions in the world outside China. *Paratirolites*? and *Shevyrevites* occur below the *Palaeofusulina* fauna but the stratigraphic relation to other ammonoid zones is not clear. *Iranites* and *Phisonites* have not been discovered in China. The genus *Iranites* ranges from the *Vedioceras nakamurai* Subzone up to the *Paratirolites* Zone, and *Shevyrevites* occurs throughout Unit 7 (Dorashamian) in Abadeh. Furthermore, KUMMEL (in TEICHERT *et al.*, 1973) described "*Pleuronodoceras*" sp. and *Pseudotirolites* sp. from the Ali Bashi Formation (Dorashamian) in Julfa, although ZHAO *et al.* questioned the identification. Very recently, TOZER (1979) pointed out the possibility that *Shizoloboceras* ZHAO *et al.* from the Upper Changxingian Dalong Formation belongs to *Paratirolites.* Furthermore, EHIRO and BANDO (1980) recently reported the occurrence of *Rotodiscoceras* sp. from a horizon about 800 m below the top of the Upper Permian Toyoma Formation in Northeast Japan.

The Dorashamian ammonoids as a whole are similar to the Changxingian ammonoids in their characteristic shape and ornamentation, which suggests that close correlations should be possible. Thus, we correlate the Dorashamian with the

Changxingian, keeping in mind the possibility that the uppermost part of the Changxing Formation and the Toyoma Formation may be younger and compared to the *Julfotoceras concavum* Zone.

Another problem is a correlation of the *Palaeofusulina* Zone throughout the Tethyan realm. According to ZHAO *et al.* (1978b) the occurrence of the *Palaeofusulina* fauna is controled by lithofacies. It continues to the highest ammonoid zone, the *Rotodiscoceras* Zone, in China wherever the limestone facies is developed, but it does not occur below the Changxingian. Very recently, RUI (1979) discriminated two subzones in the *Palaeofusulina* Zone of the Changxingian Stage, the *Palaeofusulina minima-Nankinella guizhouensis* Subzone, below, and the *Palaeofusulina sinensis* Subzone, above. He considered that the *Palaeofusulina* aff. *sinensis-Colaniella parva* Zone of the Upper Maizuru Group in Japan is equivalent to the *P. minima-N. guizhouensis* Subzone, but the Japanese *Palaeofusulina* is definitely more advanced than *minima* and above the *P. simplex-Colaniella minima* Zone which is correlated with the lower subzone in China (ISHII *et al.*, 1975).

RUI gives no detailed columns of the two *Palaeofusulina* Subzones. According to SHENG's columnar section (1963), the advanced *Palaeofusulina* appears near the base of the Changxing Limestone and WANG (1966) reported the coexistence of *Palaeofusulina* sp. and *Codonofusiella* and/or *Colaniella* in the Middle Lopingian. The fossil horizons of WANG are mostly referred to as the Wujapingian, although in places extend into the Changxingian (person. comm., SHENG, 1975). In addition to these facts, ZHAO *et al.* (1978b) also recorded the occurrence of primitive *Palaeofusulina* in association with Wujapingian *Codonofusiella,* and stated that the Changxingian Stage is characterized by the appearance of a large amount of advanced *Palaeofusulina.*

Consequently, it remains uncertain whether the *Palaeofusulina minima* Subzone is included in the Changxingian.

RUI (*op. cit.*) also mentioned the possibility that *Lepidolina kumaensis* in the Middle Maizuru Group is a derived fossil from the Maokouan beds (*Yabeina* Zone). The occurrence of *kumaensis* in the coarse-grained sandstone and conglomerate shows the secondary transportation, but it is found as individual specimens constituting sand grains or in the matrix of conglomerate, while other older fossils are always found in limestone clasts. Therefore, it is concluded that *L. kumaensis* is syngenetic with the surrounding sediments which contain *Palaeofusulina simplex*-bearing limestone lens.

Comparing the Abadeh section with the Chinese section, the *Codonofusiella kwangsiana* Zone of Unit 5 is undoubtedly coeval with the Wujapingian *Codonofusiella* Zone. The *Reichelina media* Zone of Unit 6 can also be correlated with the *Codonofusiella* Zone of Wujaping or Loping Stage by the association with *Codonofusiella* and araxoceratid ammonoids, although *R. media* is confined to the *Palaeofusulina sinensis* Subzone in South China according to RUI.

Another problem of *Palaeofusulina* Zone is an occurrence of *Palaeofusulina* aff. *fusiformis* and *P.* cf. *simplicata* from the *Colaniella-Paradunbarula* beds in sothwest Pamir, which horizon contains the Takhtabulak assemblage of brachiopods (person. comm., LEVEN, 1979). A similar occurrence was also reported by NAKAZAWA *et al.* (1975b) from Greece. The facts suggest that the *Palaeofusulina* Zone may be diachronous bewteen East and West Tethys. This must be examined in the future.

Correlation of the Permian in the Tethys province based on the above dsicussion is given in Table 3.

VII. Problems of the Subdivision of the Upper Permian

Various schemes of subdivision of the Permian System have been proposed and discussed by many authors (Table 1). This problem was recently discussed in great detail by WATERHOUSE (1976a) and KOZUR (1977b, 1978). The subdivision of the upper part of the Permian will be examined in this chapter.

1. Dzhulfian and Dorashamian

The Dzhulfian is a familiar name for many geologists, and the Guadalupian and its subdivision, Wordian and Capitanian, are used by many geologists, too. But unfortunately, they are used somewhat differently by different people. Consequently, definition of these names is needed.

SCHENCK *et al.* (1941) first proposed the name Djulfian Stage for the uppermost part of the Permian. They wrote, "But in Djulfa (Armenia) the uppermost Paleozoic strata which underlie the Lower Triassic beds carry a distinctive assemblage characterized by the cephalopod genus *Protoceras*. We suggest that the name Djulfian be employed for the uppermost Permian. Only the upper stratigraphic limit of the Djulfian Stage can be defined at the present time. This upper limit will be determined by the lowermost Triassic *Otoceras*-bearing beds."

They did not submit any section to indicate the upper limit in the Djulfa section. At the same time they proposed the Panjabian Stage for the lower Upper Permian Series (Upper Productus Limestone) and the Guadalupian for the Middle Permian. But several authors used the Dzhulfian as a post-Guadalupian or post-Kazanian Stage name (GLENISTER & FURNISH, 1961; FURNISH & GLENISTER, 1970; STEPANOV, 1973). RUZHENTSEV and SARYCHEVA (1965) employed the Guadalupian and the Dzhulfian for evaluation and description of the Dzhulfa section. They defined Dzhulfian to include the interval from the *Codonofusiella-Reichelina* horizon to the *Phisonites-Comelicania* horizon and referred the underlying Khachik beds as the Guadalupian. This scheme was followed by STEPANOV *et al.* (1969) in the study of Julfa section in Iran, but they correctly placed the *Codonofusiella* horizon in the Khachik beds and the *Phisonites-Comelicania* horizon in the 'Permian-Triassic transition

Abadeh, Iran 1)			
Hambast Formation	7	*Paratirolites* Zone	
		Paratirolites-Shevyrevutes Zone	
		Shevyrevites Zone	
	6	*Vedioceras* Zone	
		Araxoceras Zone	*R. media*
		Araxilevis Bed	
Abadeh F.	5	*Codonofusiella kawangsiana* Z.	
	4	*Sphaerulina* sp. Zone	
Surmaq Formation	3	*Orientoschwagerina abichi* Zone	
	2	*Neoschwagerina margaritae* Zone	
	1	*Neoschwagerina cheni* Zone	
		Eopolydiexodina douglasi Zone	
		Schwagerina quasifusuliniformis	
		Darvasites cf. *ordinatus* Zone	

Transcaucasia, USSR 2)	
Dorasham Beds	*Paratirolites* Beds
	Shevyrevites Beds *Iranites* Beds
	Phisonites Beds
Dzhulfa Beds	*Vedioceras-Haydenella* Beds
	Araxoceras-Oldhamina Beds
	Araxilevis Beds
Khachik F.	*Codonofusiella-Reichelina*
	Codonofusiella, Chusenella
Ar.	*Orientoschwagerina abichi*
Gnishik F.	*Chusenella, Verbeekina verbeeki, Eopolydiexodina*
Asniy F.	*Cancellina, Praesumatrina*
	Misellina ovalis
Dabalin F.	*Misellina parvicost.*
	Chalaroschwagerina, Darvasites ordinatus

Darvas, USSR 3)	
	↑
Dzhulfian	*Tschernyschevia, Uncinunellina, Reichelina*
"Capitanian"	*Stepanovites inflat. Gondolella bitteri*
Margabian	
Kuber.	*Parafusulina, Armenia*
Bolor.	*Misellina ovalis*
	M. parvicostata
	M. dyhrenfurthi
Artinsk.	*Chalaroschwagerina, Pamiria, Perrinites*
Sakmar.	*Robustschwagerina, Paraschwagerina*
Asselian	*Schwagerina, Pseudoschwagerina*

Pamir, USSR 4)	
	↑
Karabeles F.	*Palaeofusulina, Paradunbarula, Codonofusiella, Reichelina*
Gansk Fromation	*Codonofusiella, Reichelina*
	Neoschwagerina margaritae
	Neoschwagerina schuberti
	Neoschwagerina simplex
Kugergandy F.	*Cancellina, Armenia*
	Misellina ovalis
	M. aliciae, Chalaroschwagerina
	Perrinites, Prostacheoceras
Bazardara F.	*Perrinites, Neocrimites*

Afghanistan 5)	
	Codonofusiella, Reichelina
P2m	*Neoschwagerina margaritae*
	Neoschwagerina schuberti
	Neoschwagerina simpl.
P2kb	*Cancellina, Schw. quasifusulinif. Polydiexodina paraec.*
P2ch	*Pseudofusulina ambig. Misellina ovalis*
P1a	*Chalaroschwagerina vulgaris, Darvasites ordinatus*
P1s	*Robustoschwagerina geyeri, Paraschwagerina inflata*
P1as	*Schwagerina glomerosa Pseudoschwagerina*

Thailand 6)
Palaeofusulina sinensis
Lepidolina multisep.
Colania douvillei, Verbeekina verbeeki
Neoschwager. haydeni
Afghanella schenki, Praesumatrina schel.
Neoschwagerina simplex
Maklaya sethaputi
Maklaya pamirica
M. saraburiensis
Misellina confrag.
Misellina otai
Triticites ozawai-Pseudoschwagerina yanagidai

South China 7)		
Changxingian	*Palaeofusulina*	*Rotodiscoceras* Z.
		Pseudotirolites-Pleuronodoceras
		Pseudostephanites-Tapashanites Zone
Wujapingian	*Codonofusiella*	*Sañyangites* Zone
		Araxoceras-Konglingites Z.
		Anderssonoceras-Prototoceras Z.
Maokouan		"*Yabeina*" Zone
		Neoschwagerina Zone
		Cancellina Zone
chihsian		*Misellina* Zone
Mapingian		*Pseudoschwagerina* Zone

Southwest Japan 8)	
Mitaian	*Palaeofusulina sinensis, Colaniella parva*
Kuman	*Reichelina* cf. *media, Codonofusiella kwangsiana* Zone
	Lepidolina kumaensis Z.
Akasakan	*Colania douvillei, L. multiseptata* Z.
	Neoschwagerina margaritae Zone
	Neoschwagerina craticulifera Z.
Nabeyaman	*Neoshwagerina simplex - Cancellina nipponica* Z.
Sakamotozawan	*Misellina claudiae* Zone
	Pseudofusuina ambigua Zone
	Chalaroschwagerina vulgaris Zone
	Triticites simplex Zone

Northeast Japan 9)	
Toyoma Formation	*Rotodiscoceras, Colaniella parva*
	Eumedlicottia, Araxoceras
	Stacheoceras
Kanokura Formation	*Lepidolina kumaensis* Zone
	Lepidolina multiseptata Zone
	Colania douvillei
	Monodiexodina matsubaishi Zone
Sakamotozawa F.	*Pseudofusulina ambigua, Pseudofusulina fusiformis* Zone
	Chalaroschwagerina vulgaris Zone
	Monodiexodina, Zellia nunosei Z.

Salt Range, Pakistan 10)	
Basal unit of Kathwai	
Chhidru Formation	*Cyclolobus, Colaniella, Codonofusiella, Reichelina*
	Colaniella minima, Codonofusiella, Reichelina, Waagenophyllum
Kb.	
Wargal F.	*Neoschwagerina margatitae*
Amb Formation	
	Glossopteris, Gnagamopteris
	Monodiexodina kattaensis
Sardhai Formation	
Warchha Formation	
Dandot Formation	
Tobra Formation	

Kashmir, India 11)		
Zewan Formation	E	*Claraia bioni*
	D	*Gondolella subcarinata*
	C	*Cyclolobus*
	B	
	A	*Colaniella minima, Abadehella*
Panjal volc. & Perm. Gondw.	Panjal volcanic rocks	Mamal beds
		Munda beds
		Morahoma beds
		Vihi beds
		Nishatbagh b.
Agglomeratic Slate Group	volcanic flow II	
	Buccanopsis, Warthia	
	Praeundulomya	
	Taeniothaerus, Buxtonia	
	volcanic flow I	
	Barren zone	
	Eurydesma-Deltopecten	
	Fenestella	

Table 3. Correlation chart of the Permian in the Tethys Province based on various sources; 1) present paper, 2) RUZHENTSEV and SARYCHEVA, 1965; LEVEN, 1975, 1979, 3) LEVEN and SCHSERBOVICH, 1978; LEVEN, 1979, 4) LEVEN, 1967, 1979; GRUNT and DIMITRIEV, 1973, 5) LYS and LAPPARENT, 1971; LEVEN *et al.*, 1975 6) INGAVAT *et al.*, 1980, 7) SHENG, 1963; ZHAO *et al.*, 1978, 8) TORIYAMA, 1967; KANMERA and NAKAZAWA, 1973, 9) KANMERA and MIKAMI, 1965; EHIRO and BANDO, 1980, 10) NAKAZAWA and KAPOOR, 1977, 11) NAKAZAWA *et al.*, 1975.

beds'. The Permian age of the *Tompophiceras* (=*Iranites*) to the *Paratirolites* interval, which was considered as the Induan of the Lower Triassic by RUZHETSEV and SARYCHEVA, is now generally agreed among the world geologists. ROSTOVTSEV and AZARYAN (1973) proposed a new stage name, Dorashamian, for this uppermost Permian. The name is adopted by KOZUR (1977b) as the upper substage name of the Dzhulfian Stage, and by WATERHOUSE (1976a) as the uppermost Permian stage name.

The Dorashamian of WATERHOUSE is constituted by three substages, that is, the Vedian (*Phisonites* beds), the Ogbinan (*Shevyrevites* beds to *Paratirolites* beds) and the Gangetian (*Otoceras* beds). The Vedian Stage is, however, difficult to be applied to other regions, because the characteristic ammonite, *Phisonites* has a very limited geographic distribution. The problem of *Otoceras* beds will be discussed in a separate section.

RUZHENTSEV and SARYCHEVA (1965) and WATERHOUSE (1976a) included the *Codonofusiella-Reichelina* beds in the Dzhulfian, but many authors (STEPANOV *et al.*, 1969; FURNISH, 1973; TARAZ, 1974; KOZUR, 1977b) preferred the base of the *Araxilevis* beds as the base of the Dzhulfian. The small-fusulinid fauna recently discovered from the *Araxilevis* beds in Abadeh is similar to that of the underlying Unit 5, but can be distinguished from the latter in the predominance of *Reichelina* and the same fauna continues up to the *Araxoceras* Zone. The brachiopod fauna is more like that of the Dzhulfian than to the Abadeh Formation and the Khachik beds. Furthermore, the *Araxilevis* beds in Abadeh yield several nautiloids (*Domatoceras* sp. and *Syringonautilus* sp.) and an ammonite *Pseudogastrioceras*, all of which are found in the Dzhulfa beds. Accordingly the *Araxilevis* beds are reasonably referred to as the basal unit of the Dzhulfian.

The Dorashamian is here used as a distinct stage name, because it is clearly distinguished from the Dzhulfian by distinctive ammonoids and fusulinids. The Dzhulfian (s.s.) is characterized by araxoceratid ammonoids (*Araxoceras, Vedioceras, Urartoceras, Avushoceras*, etc.) and the *Codonofusiella-Reichelina* fauna. On the contrary, the Dorashmian is represented by ammonoids which belong to Xenodiscidae (*Phisonites, Iranites,* and *Shevyrevites*) and Dzhulfitidae (*Paratirolites*) in Iran and Transcaucasia and Pseudotirolitidae, Pleuronodoceratidae, and Tapashanitidae in South China. The advanced *Palaeofusulina* fauna is diagnostic of the Dorashamian.

The Changxingian Stage was adopted as the uppermost Permian stage by FURNISH (1973) above the Chhidruan, and by LEVEN (1975b) above the Dzhulfian. But it cannot be concluded at present whether the base of the Changxingian coincides with the top of the Dzhulfian (s.s.) as discussed already, and the Chhidru Formation, the type of the Chhidruan, is now concluded to be Abadehian-Dzhulfian. Dzhulfian and Dorashamain are more preferrable as stage names, because they are clearly defined paleontologically and stratigraphically in the same continuous section. The

Dzhulfian here defined is the same as the Baisalian of WATERHOUSE (1973, 1976a).

2. Abadehian

The Abadehian Stage name proposed by TARAZ (1971) as the post-Guadalupian and pre-Dzhulfian Stage is accepted by KOZUR (1977b, 1978). WATERHOUSE (1976a) subdivided the Dzhulfian Stage into two substages, Urushtenian and Baisalian. He tentatively used the Urushtenian instead of the Abadehian because of insufficient fossils of the Abadeh Formation at that time.

The Abadehian is undoubtedly pre-Dzhulfian, because the Abadeh Formation, the type of Abadehian, is directly overlain by the Dzhulfian beds at Abadeh, but the stratigraphic relation with the Guadalupian or its upper half, Capitanian beds in the United States cannot be verified. Therefore, a careful examination on the correlation between the two remote regions is required to conclude the post-Guadalupian age of the Abadehian.

In this connection, the occurrence of *Yabeina texana, Codonofusiella extensa, Reichelina lamarensis* and *Paradoxiella pratti* from the Lamar Limestone, the uppermost member of the Bell Canyon (Capitanian) in Texas is important. *Yabeina texana* was first considered to be a primitive form of the genus by SKINNER and WILDE (1966) in having a small shell provided with a small number of volutions and poor development of secondary septula. MINATO and HONJO (1959) pointed out that *texana* is identical in septal development with *Y. ozawai* which occurs in the *Neoschwagerina margaritae* Zone in Japan. Later, ROSS and NASSICHUK (1970) expressed the opinion that *Y. texana* has advanced features of septula comparable to that of *Yabeina globosa* and correlated the Lamar Member with the *Yabeina globosa* or *Yabeina-Lepidolina* Zone in Japan. This correlation was approved by WILDE (1975). The coexistence of *Codonofusiella* and *Reichelina* seems to support this correlation.

As discussed already, the Abadeh Formation is believed to be younger than the *Yabeina globosa* Zone, because the underlying *Orientoschwagerina abichi* Zone of Unit 3 can be compared to the *Yabeina* Zone and Unit 5 is correlated with the Wujapingian *Codonofusiella* Zone.

The La Colorada beds which occupy the uppermost part of the Permian at Coahuila, in Mexico, are generally believed to be a Lamar equivalent, but there is no convincing paleontologic evidence in support of this. The beds yield *Eoaraxoceras ruzhencevi, Neocrimites* sp., *Stacheoceras* cf. *tridens, Propinacoceras* n. sp., *Episageceras* cf. *nodosum* and *Kingoceras kingi* (SPINOSA *et al.*, 1970). The fauna is compared to the Amarassi fauna of Timor. FURNISH (1973) introduced the Amarassian Stage above the Capitanian, but considered that the Lamar Member is Amarassian. However, the La Colorada beds are about 600 m above the beds (Bed 43 of NEWELL, 1957) which have a typical Capitanian fauna and about 200 m above the Zone of *Kingoceras*. Recent discovery of *Eoaraxoceras ruzhencevi* from the basal part of the *Araxoceras* Zone at Abadeh suggests the post-Guadalupian age of the La Colorada beds.

A direct comparison of the Abadehian fauna with the Amarassi fauna is difficult, but the former fauna is compared to that of the Kalabagh-Lower Chhidru in having *Xenodiscus carbonarius, Codonofusiella-Reichelina* assemblage and a few common species of foraminifers and brachiopods. The Kalabagh-Lower Chhidru brachiopod fauna is, in turn, very similar to the Amarassi fauna. La Colorada beds, Amarassi "beds", Kalabagh-Lower Chhidru beds and Abadeh Formation are considered to be nearly time-equivalent, that is, between Capitanian and Dzhulfian in age.

The name Abadehian is accepted rather than Amarassian for the post-Guadalupian and pre-Dzhulfian stage name, because Amarassi fossils are all collected from loose blocks, of which the stratigraphic position is uncertain. The Abadehian has a priority to the Urushtenian and the faunas are now clarified in detail.

The brachiopod and foraminiferal faunas of the Abadehian Stage show a transitional character from the "Guadalupian" (pre-Abadehian) to the Dzhulfian. *Abadehella tarazi, A. biconvexa, A. coniformis, Discospirella plana, D. minuta* and *Hemigordius abadehensis,* n. sp. are characteristic foraminifers. Fusulinids are represented almost exclusively by small ones, such as *Sphaerulina, Codonofusiella* and *Reichelina.* The only exception is a rare occurrence of *Chusenella,* but the later stage is represented by *Codonofusiella kwangsiana,* etc. with no larger fusulinids. *Sweetgnathodus iranicus, S. sweeti, Merrillina divergens* and *Gondolella bitteri* are found in the Abadehian, and KOZUR (1978) defined the Abadehian as the *Merrillina divergens-Stepanovites inflatus-Gondolella bitteri* assemblage zone, although *bitteri* flourished in the Lower Dzhulfian based on our data in Abadeh. According to KOZUR and MOSTLER (1976) *Merrillina divergens* described by CLARK and BEHNKEN (1975) from the Capitanian Upper Gerster Formation, in the United States, is not *divergens,* but is an intermediate form between *M. galeata* of Sicily and Abadehian *divergens.* This form was named *praedivergens* by KOZUR.

3. Otoceras beds and their correlation

Evaluation and correlation of the *Otoceras* beds have a prime importance for discussing the Permian-Triassic boundary and the group extinction through Permian-Triassic transition.

Since WAAGEN and DIENER (1895) referred the *Otoceras-Ophiceras* beds as a basal unit of the Lower Triassic and proposed the Gangetian Substage of the Brahmanian Stage, many authors accepted the base of the *Otoceras-Ophiceras* beds as the base of the Lower Triassic, that is, the beginning of the Mesozoic. Recently, however, NEWELL (1973, 1978) expressed the opinion that the Permian-Triassic boundary should be drawn at the top of the *Otoceras-Ophiceras* beds, and WATERHOUSE (1978) insisted on an even higher boundary, namely, at the base of the Smithian Stage of TOZER (the *Meekoceras-Owenites* Zone). On the other hand, KOZUR (1974, 1977a, b) claims that the *Otoceras* Zone is a Dorashamian equivalent and the boundary is taken at the *Otoceras woodwardi* Zone/*Ophiceras commune* Zone boundary. KOZUR's opinion cannot be accepted on the basis of the following reasons which indicate the younger age of the *Otoceras* Zone (NAKAZAWA *et al.*, 1980).

1) *Otoceras* cf. *woodwardi* occurs in the yellowish grey, micaceous shale of the basal Triassic near Nanjing in South China (HSU, 1937). This is recently reconfirmed by TOZER (1980). The *Otoceras* beds disconformably overlie the *Pleuronodoceras*-bearing Dalong Formation of the Changxingian age and contain *Ophiceras* cf. *serpentinum* and *Anodontophora*? sp. (ZHAO & ZHENG, 1978a). The beds are referred to be equivalent to the *Claraia wangi* beds, the basal unit of the Lower Triassic in China (CHEN, 1978).

2) As already discussed, the basal part of Unit a (stromatolite beds) in Abadeh section is correlated with the *Otoceras woodwardi* Zone in Kashmir, probably its upper part, based on the conodont zonation. Unit a is above the Dorashmian *Paratirolites* beds.

3) *Julfotoceras tarazi*, the ancestral form of *Otoceras woodwardi* occurs in the Dorashamian in Abadeh and Julfa (BANDO, 1973, 1979). No typical Dorashamian ammonoids have ever been found in the *Otoceras* bed.

4) Several Lower Triassic bivalves, such as *Eumorphotis venetianan, E.* aff. *bokharica* and *Leptochondria minima,* are common in the *Otoceras woodwardi* Zone in Kashmir, but not found in the Dorashamian.

5) The characteristic Dorashamian conodonts, such as *Gondolella orientalis* and *Anchignathodus julfensis* have not been discovered in the *Otoceras* beds. The lower part of the *Otoceras woodwardi* Zone is represented by long-ranging *Anchignathodus typicalis* (*minutus* of authors) and *Gondolella carinata* only, and the upper part by the association of *Anchignathodus parvus* with *typicalis* and *carinata* (NAKAZAWA *et al.*, 1980). One problem is the occurrence of *orientalis* and *subcarinata* from a horizon about 3 m above the base of the Lower Triassic in Section H (Hor. H90), which is included in the *Isarcicella isarcica* Zone. It is not sure whether these fossils are secondarily derived or not.

Another important problem is a biostratigraphic position of *Otoceras concavum*, because the species is very similar to *Julfotoceras tarazi* of Dorashamian and is considered to be congeneric with the latter. It occurs below the *Otoceras woodwardi borealis* Zone in Arctic Canada (TOZER, 1967). Recently WATERHOUSE (1976b, 1978) announced the occurrence of *concavum* from the base of the Panjang Formation in West Nepal in association with many productid species. At first he correlated this part with Unit E_1 of the Khunamuh Formation in Kashmir which comes beneath the *woodwardi* beds.

It is probable that the *O. concavum* Zone occupies a position between the *Paratirolites* Zone and the *O. woodwardi* Zone, and whether the *O. concavum* Zone should be included in the Permian or in the Triassic is an open question.

VIII. Sedimentary Environments

1. Permian Period

The Permian strata in Abadeh region are characterized mostly by bedded limestones of various thickness. Such a sequence is generally considered as the basin facies or "deeper water" facies on the carbonate shelf (or platform) margins (THOMSON & THOMASSON, 1969; ENOS, 1974; WILSON, 1975; COOK & ENOS, eds., 1977). However, if we examine the limestones in this area on the characteristics of "deeper water" limestones of WILSON (1969), only the main part of Unit 2 can be referred to belong to that facies, because in other units pelagic fossils are very poor, benthonic macrofossils including algal fragments are predominant, the stratification is fairly continuous and slumping sedimentary structures frequently seen in "deeper water" limestones are lacking. All these characters suggest a rather shallow marine environments. Furthermore, several sedimentary structures typical of very shallow-water condition, such as geopetal structure, tabular stromatolitic structure, birds eye structure and mud-ball structure are also observed in some units.

Most of the limestones are algal calcarenite or calcilutite with lime-mud matrix. They contain many non-fragmented macrofossils larger than granule-size and heterogeneous in size distribution, but the macrofossils do not make a framework and in most cases the fabric is an algal bioclastic framework of coarse-sand size. It should be mentioned for sedimentological consideration that there are no limestones with sparry calcite with the exception of Unit 1 at Surmaq, while algal fragments are common throughout the Permian (Fig. 4).

Concerning the biogenic constituents, algal and brachiopod fragments are common in most cases, but fusulinids predominate in Unit 1 and dascycladacean algae in Unit 5. Unit 7 and the upper part of Unit 6 are poor in bioclasts. Accordingly, it is difficult to estimate the environment solely on the faunal contents. On the other hand, the vertical variation of lime mud content (Fig. 4, left column) seems to reflect a vertical environmental change.

The paleoenvironment of carbonate shelf has been discussed by many authors in relation to sedimentary facies and biofacies, among which the models of WILSON (1974, 1975), ARMSTRONG (1974) and TOWNSON (1975) are useful for considering the present area.

Unit 1

Unit 1 is composed mostly of bedded limestones accompanied by shales and chert nodules. The limestones examined are mostly fusulinid-bearing sampled primarily for the purpose of zonation and not for sedimentological analysis. Most of the examined samples are biomicrite, but some rocks of the Surmaq section can be called grainstones in DUNHAM's classification (1962) (Pl. 3, Fig. 1). Wavy bedding planes, observed at several horizons, indicate current or wave action. Fusulinids are common throughout. Brachiopods occur at several horizons and are especially abundant near the top of the unit. Colonial corals occur but are not abundant. Mud content was not systematically observed, but the lithofacies and biofacies suggest an open neritic environment similar to the swell of TOWNSON (1975). The brachiopod assemblage near the top of the unit consists of *Neochonetes, Avonia, Vediproductus, Linoproductus, Martinia,* etc., all fond of soft clay bottom of quiet environments. This shows a transition to the deeper facies of Unit 2.

Unit 2

Unit 2 is characterized by grey, bedded limestones alternating with black chert beds or irregular nodules (Pl. 5, Fig. 5). The main part of the unit has suffered from recrystallization and the original texture and mud content are difficult to determine (Pl. 3, Fig. 3). However, the lowermost part has more than 50% lime mud and therefore is classified as lime mudstone with some spiculitic packstones. According to recent models of shallow marine carbonate sedimentation of IRWIN (1965) and HECKEL (1972), the lime mudstone facies shows both a "deeper water" condition or a very shallow-water condition. Shaly and shelly calcilutite is characteristic in the former. Wackestones-packstones of Unit 2 are similar to those of the "deeper water" facies (Pl. 3, Fig. 2). It is pertinent to note that lime mud is now accumulating in the axial part of the present Persian Gulf (PURSER, 1973).

Chert beds or nodules contain many sponge spicules, but marcofossils are scarce and fusulinids are limited to a few horizons. All these characters show that Unit 2 belongs to facies 1 of WILSON (1974) and ARMSTRONG (1974), thought to represent the basin environment. It also corresponds to facies 1 and 2 of TOWNSON (1975) commonly found in basin-slope sediments.

Unit 3

Unit 3 is composed of alternations of thick- and thin-bedded limestones. The mud content is small, usually less than 10%.

Fossils are represented by fusulinids, brachiopods and algae accompanied by colonial corals and sponges. Many of the limestones are classified as dascycladacean packstones and wackestones with many bioclasts of various kinds and sizes (Pl. 3, Figs. 4 and 5). The facies of Unit 3 is most similar to facies 5 of the open shelf of ARMSTRONG (*op. cit.*) and the marine restricted shoal of Facies belt 7–8 of WILSON (1975). The occurrence of *Richthofenia, Leptodus, Orthothetina* and *Chonostegoides* assemblage supports this conclusion.

Unit 4

This unit consists of black shales with limestone interbeds, and is distinguished from other units by the predominance of terrigenous muddy materials. The mud content of the limestones gradually increases upward reaching a maximum in the lower part of Unit 4b, then decreases with lime-mudstone intercalations. The upper part of Unit 4b is similar to Unit 3 in containing a large amount of algal fragments and a small amount of mud (Pl. 3, Fig. 8), but differs in developing parallel lamination produced by a horizontal arrangement of small algal plates (Pl. 4, Figs. 1–3). Lime mud-poor limestone alternates with lime mud-rich limestone. These features suggest a lower energy condition than that of Unit 3.

Larger fusulinids rapidly decrease, and are replaced by smaller foraminifers flourished at this stage. This unit seems to have deposited under the open lagoonal conditions of TOWNSON (1975). The accumulation of terrigenous mud materials on a shallow but calm bottom also favours the lagoonal hypothesis.

The existence of stromatolitic beds with geopetal structure and much mud in the lower part of Unit 4b indicates a sporadic intertidal environment (Pl. 3, Fig. 6).

Unit 5

The main part of Unit 5 is composed of bedded limestones with chert nodules, and the upper and lower parts are composed of alternations of limestone and shale. The microtexture of the limestone is similar to that of Unit 4b and Unit 3 in having abundant algal fragments. The mud content is small in the lower part, less than 10%, as in the upper part of Unit 4b. That of the upper part fluctuates considerably, but a rather rapid increase in mud towards the top of the unit is recognizable.

Biofacies is represented mainly by microfossils, such as fusulinids and foraminifers, and algal clasts. This unit is considered to represent a transitional facies from that of Unit 4 to Unit 6.

Units 6 and 7

Unit 6 is made up of alternations of dark grey limestone and dark greenish grey shale. Unit 7 consists mostly of reddish or pinkish limestones with thin reddish muddy intercalations.

Based on mud content, all the limestones of both units are classed as lime mudstones. The lower part of Unit 6 contains brachiopods, crinoids, solitary corals and bryozoans. Smaller fusulinids and foraminifers are also common but have decreased in number. The microscopic texture is that of grain-floated biomicrites (Pl. 4, Fig. 4). The brachiopod fauna is constituted of species of soft clay bottom bathed by current. *Araxilevis, Tyloplecta* and *Leptodus* are examples.

The upper part of Unit 6 and Unit 7 contain few bioclasts in the matrix (Pl. 4, Figs. 5 and 6). Ammonoids, conodonts and ostracods are common. Birds eye and mud-ball structures and mud cracks are frequently observed (Pl. 4, Figs. 7 and 8; Pl. 5, Fig. 6), suggesting intertidal or even supratidal conditions.

The change of litho- and biofacies from the lower part of Unit 6 to the succeeding one tells of a transition from open lagoonal to restricted lagoonal environments, even though pelletal limestone is absent in this region. The origin of the nodular bedding commonly found in Unit 7 is uncertain.

Very interesting is a decrease of boron and lithium in the middle of Unit 7 and at the 7/a boundary. This may suggest fresh-water inflow to the basin as will be discussed later. The common occurrence of ammonoids in such a basin is problematical. They may have been transported from the open sea by a current.

2. Early Triassic Period

"Colonial limestones" (algal biolithites) of Unit a

The Lower Triassic System begins with a brownish to greenish shale bed some 15 to 30 cm in thickness. A small solitary body of "colonial limestone" first appears in this bed (Fig. 11). The shale bed is overlain by cliff-making bedded limestones about 2 m thick, containing many colonial limestones. Two kinds of limestone bodies are distinguished, that is, a massive type and a planar type. The former one clearly cuts the surrounding bedded limestones, but the latter type merges into thin-bedded limestone. Parallel layering is not observed and they can not be considered normal stromatolites. Nevertheless, algal structure is visible in well preserved specimens (Pl. 5, Figs. 1, 3 and 4). Therefore, they are assigned to thrombolites which were named by AITKEN (1967) for non-laminated stromatolites.

The massive bodies resemble the digitate stromatolites described from Cambrian and Ordovician rocks in Missouri, by HOWE (1966). The digitate columns are surrounded by weathered, brownish, impure micritic limestone, similar to matrix reported by HOWE.

The planar stromatolites have the same structure as the massive type under the microscope and is considered to be of algal origin, as was concluded by HOWE. They grade into the surrounding impure micritic limestones which contain ostracods and other small, thin shell fragments.

According to AITKEN (*op. cit.*) thrombolites are cryptoalgal biolithites formed in lower tidal to subtidal environments with low turbulent energy. The absence of oolites and intraclasts and the isolated occurrence of stromatolitic bodies in our area also suggest relatively calm, intertidal, or subtidal, conditions.

The regression at the Permian-Triassic boundary is reflected in the high content of insoluble residue in the boundary rocks (Fig. 15).

Main part of Unit a

Unit a is composed mostly of alternations of limestone, yellow shale, and thin-bedded limestones. Detailed observations were made on the lowermost 52 m of Section C (Fig. 14). Individual limestone beds are mostly 2 cm to 5 cm thick and very fine-grained. Due to secondary recrystallization, the sedimentary features are difficult to study, but parallel lamination is observed on weathered cross sections of beds at several horizons (Pl. 6, Figs. 1, 2). Presumably, the lamination is a common primary sedimentary structure. Sole markings, such as flute moulds (Pl. 6, Fig. 7), current crescent moulds (Pl. 6, Fig. 8), and gutter cast(?) are found in Beds 15, 19, 21 and 23 of Section C. In general, they show southerly current (Fig. 14). Ripple marks are observed in Beds 18 and 21. Graded texture, convolution and ripple lamination, which are common in the typical turbidites, are uncommon, or not observed, however.

Shells of ammonoids and claraias are crowded on the bedding planes at many horizons in the lower 20 m part of the unit.

Trace fossils are abundant especially in platy limestones above the stromatolitic beds and from 40 m to 52 m above the base of the unit. They are represented by worm burrows arranged parallel to the bedding plane, some of which are identified as *Chondrites* sp. (Pl. 6, Fig. 5) and *Megagrapton* type fossils (Pl. 6, Fig. 6). *Zoophycos*- and *Granularia*-like fossils are also found, but no trace fossils belonging to *Skolithos* facies (SEILACHER, 1967) could be found. Judged by the very fine grain-size of the limestones, the sedimentary structures, trace fossils of *Zoophycos* and *Chondrites,* and the occurrence of shells mentioned above, the limestones of the Lower Triassic must have been deposited in a relatively deeper sea bottom, presumably infraneritic part of very wide shelf and a little deeper portion, by weak turbidity current of low density.

3. Environmental changes throughout the Permian and Early Triassic Periods

The environmental changes throughout the Permian and Early Triassic can be summarized as follows (Fig. 15).

The Abadeh region was emergent in the late Carboniferous. A transgression started in the Artinskian and the area was submerged under an open, shallow sea (Unit 1). The basin was deepened to the lower slope or basin environment in the stage of Unit 2. After that, overall shallowing of the sea proceeded from an open shelf on the swell to a restricted lagoon or platform through an open lagoon. At the end of the Permian, the area was again emergent as a flat coastal plain. After a short interval of emergence at the Permian-Triassic boundary, the area was rapidly submerged with infraneritic or even deeper environment through littoral conditions for

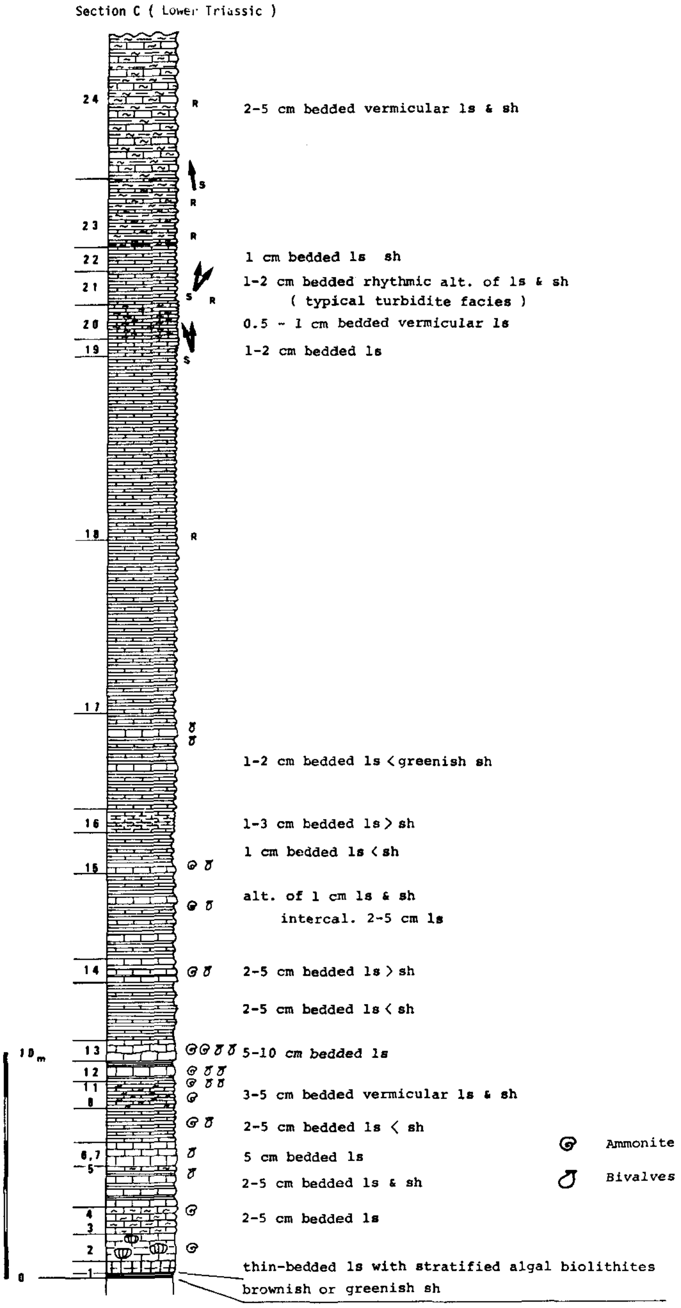
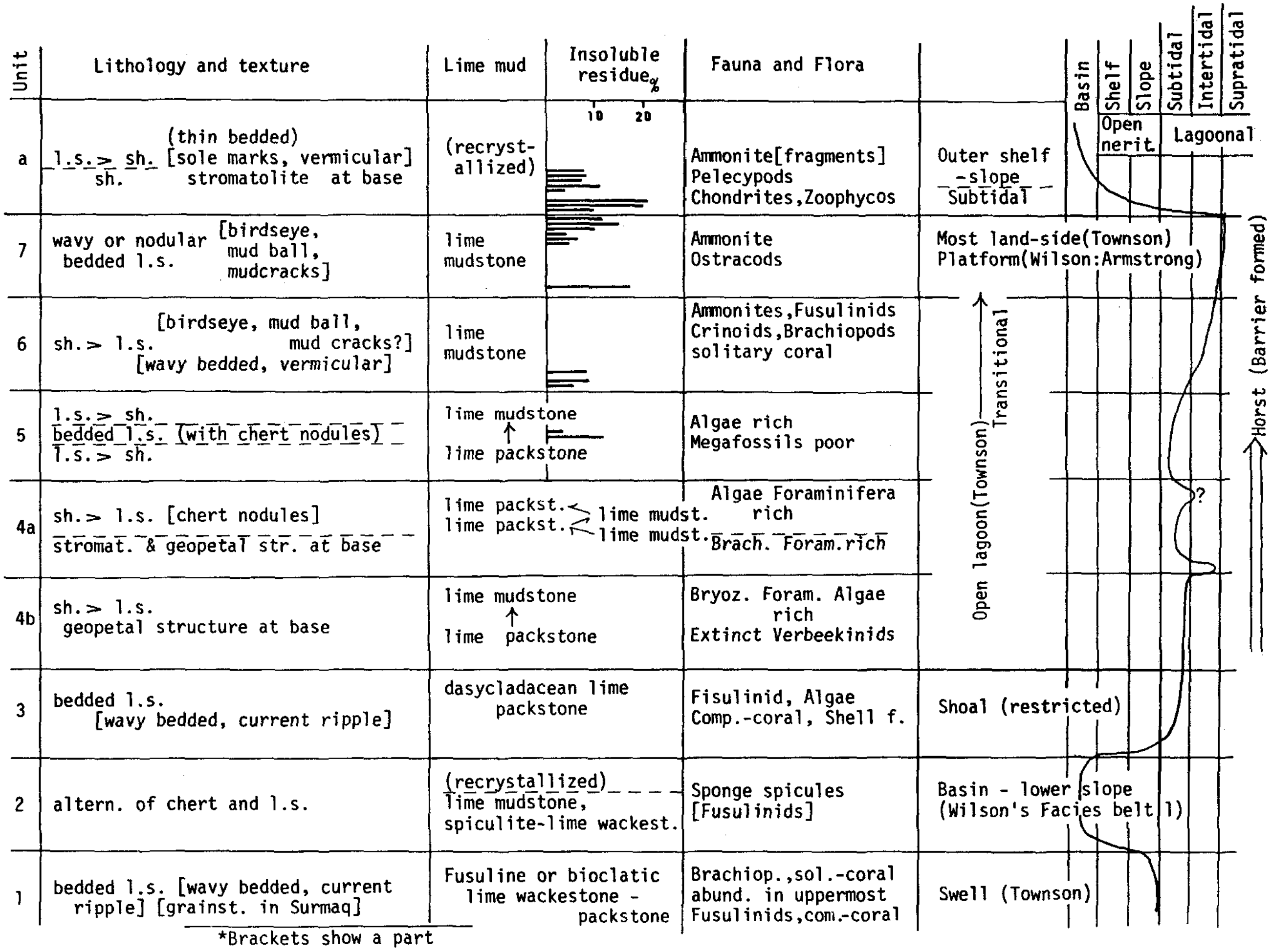


Fig. 14. Detailed columnar section of Unit a of Section C showing sedimentary feature and paleocurrent direction. R: ripple mark, S: sole mark.



Unit	Lithology and texture	Lime mud	Insoluble residue%	Fauna and Flora	
a	(thin bedded) l.s.> sh. [sole marks, vermicular] sh. stromatolite at base	(recrystallized)		Ammonite[fragments] Pelecypods Chondrites,Zoophycos	Outer shelf -slope Subtidal
7	wavy or nodular bedded l.s. [birdseye, mud ball, mudcracks]	lime mudstone		Ammonite Ostracods	Most land-side(Townson) Platform(Wilson:Armstrong)
6	sh.> l.s. [birdseye, mud ball, mud cracks?] [wavy bedded, vermicular]	lime mudstone		Ammonites,Fusulinids Crinoids,Brachiopods solitary coral	Open lagoon(Townson) → Transitional
5	l.s.> sh. bedded l.s. [with chert nodules] l.s.> sh.	lime mudstone ↑ lime packstone		Algae rich Megafossils poor	
4a	sh.> l.s. [chert nodules] stromat. & geopetal str. at base	lime packst. ⇄ lime mudst. lime packst. ⇄ lime mudst.		Algae Foraminifera rich Brach. Foram.rich	
4b	sh.> l.s. geopetal structure at base	lime mudstone ↑ lime packstone		Bryoz. Foram. Algae rich Extinct Verbeekinids	
3	bedded l.s. [wavy bedded, current ripple]	dasycladacean lime packstone		Fisulinid, Algae Comp.-coral, Shell f.	Shoal (restricted)
2	altern. of chert and l.s.	(recrystallized) lime mudstone, spiculite-lime wackest.		Sponge spicules [Fusulinids]	Basin - lower slope (Wilson's Facies belt 1)
1	bedded l.s. [wavy bedded, current ripple] [grainst. in Surmaq]	Fusuline or bioclatic lime wackestone - packstone		Brachiop.,sol.-coral abund. in uppermost Fusulinids,com.-coral	Swell (Townson)

*Brackets show a part

Fig. 15. Sedimentary and biological characteristics of each unit and the sedimentary environment,

a short time.

Such environmental changes must have been related to the block movements in this area as mentioned in Chapter 2. The Abadeh-Hambast belt lies between the Eqlid metamorphic belt on the southwest and the Gavkhuni depression on the northeast. As shown in Fig. 2, Jurassic rocks directly overlie the Precambrian metamorphic basement in the Eqlid belt, which separates the Abadeh-Hambast belt from the geosynclinal Zagros basin or folded belt. Accordingly, the study area was occupied by the marginal sea of the Iran microcontinent facing the Zagros geosynclinal sea beyond the Eqlid barrier.

4. Paleosalinity deduced from boron and lithium content

It is well known that boron content of water is related to the salinity — the lower the salinity, the lower the content. The results of many investigations show that boron is a useful indicator of salinity of the water in which the sediments were accumulated. KEITH and DEGENS (1959) found that marine shales contain more lithium and boron than those of fresh water. OHRDORF (1968) also stated that Carboniferous shale of fresh-water origin in Germany has less lithium than that of marine shale. Therefore, lithium in sedimentary rocks may be another useful indicator of paleosalinity (WEDEPOHL, 1970).

It is considered that boron and lithium are concentrated in clay minerals, such as illite and montmorillonite, by adsorption depending on their concentrations in the water (HIRST, 1962).

Our chemical analyses of boron and lithium were done by A. INAZUMI of Kagawa University on the <2 micron fraction of insoluble residues of limestones taken from Section H, and Sections A and B in Hambast Valley. The <2 micron fraction of insoluble residue was separated using the method of WALKER (1963). Boron was determined colorimetrically and lithium by atomic adsorption spectroscopy. The adjusted boron content was calculated according to the formula proposed by WALKER (*op. cit.*).

The results are given in Figs. 16 and 17. Fig. 16 shows vertical variation of adjusted boron and lithium content in Unit 3 to Unit a. Unit 3 to Unit 4a and Unit 7 are poor in boron and lithium. In Unit 4b and Unit 5, the lithium content fluctuates considerably and is not always concordant with variation of boron. But both elements in general are much more concentrated than in the other parts of the sequence.

Fig. 17 gives the result of detailed analysis from Unit 6 to the lower part of Unit a. A similar pattern of vertical changes in boron and lithium is recognized. It is clear that both elements rather rapidly decrease from Unit 6 to Unit 7 reaching a minimum at about the middle of Unit 7, then increase upward with a sudden drop

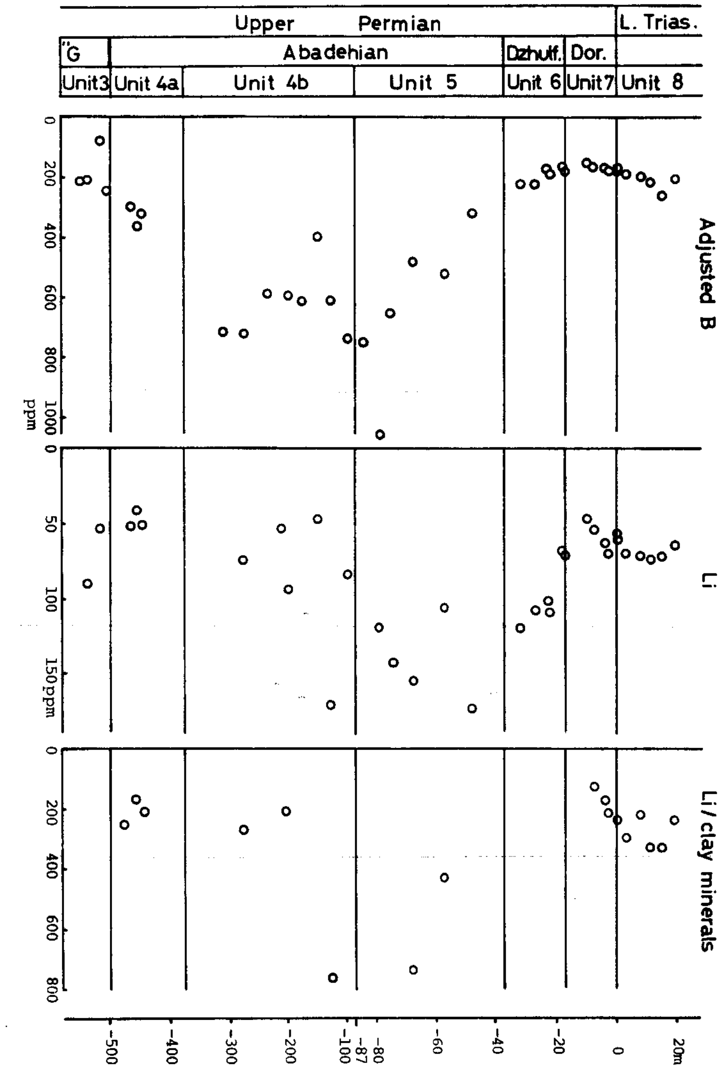


Fig. 16. Vertical variation of boron and lithium content of Units 3–8 (8=a).

at the Permian-Triassic boundary. The decrease of boron and lithium may be explained by the fresh-water influence of the restricted lagoon at that time. However, it is difficult to interprete the low content in Unit 3 and Unit 4a, since an open neritic environment is deduced from the sedimentological analysis as discussed in the previous section. The problem is not resolved.

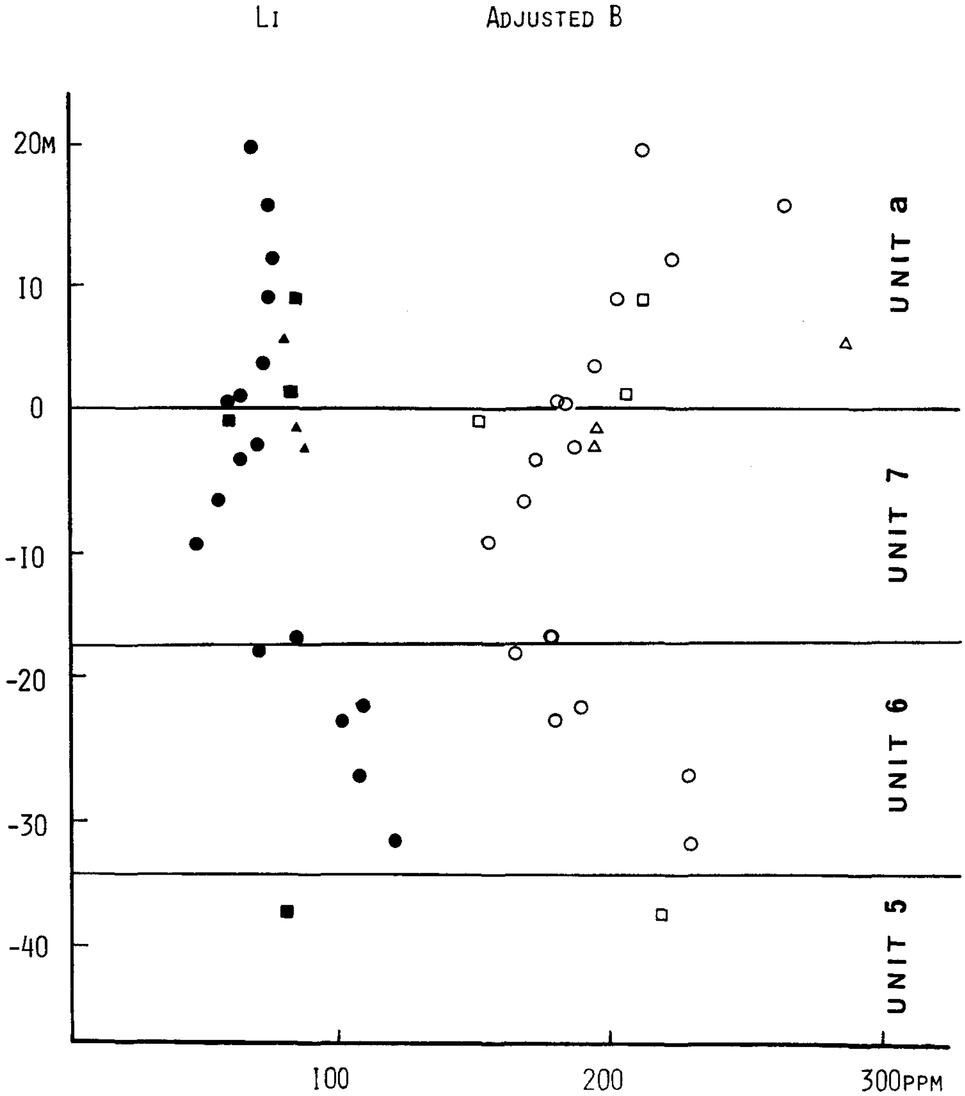


Fig. 17. Detailed vertical variation of boron and lithium content of Units 5–a. Circle: Section H, triangle: Section A, square: Section B.

IX. Faunal Changes

As discussed in the previous chapter, Fusulinacea, smaller Foraminifera and Brachiopoda are the main constituents of the Permian marine faunas. Ammonoidea and Conodontophorida became predominant in the Late Permian (Fig. 18). Anthozoa, Gastropoda, Bivalvia and Ectoprocta (Bryozoa) are subordinate elements in the

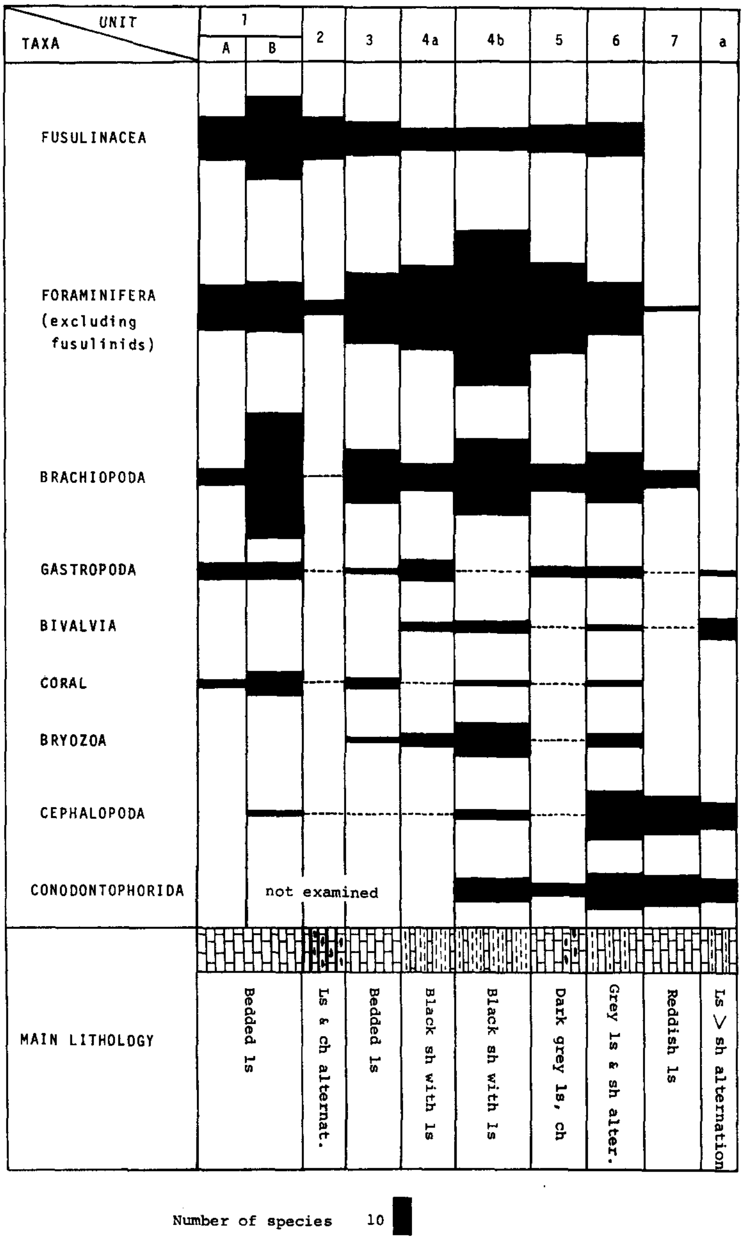


Fig. 18. Stratigraphic distribution of taxa in terms of numbers of species.

Permian. Dascycladacean algae, sponge spicules, and Ostracoda are commonly found in some parts of the sequence. They are important in considering the paleoenvironment but not specifically determinable.

The Triassic faunas of Iran are represented by Ammonoidea, Conodontophorida, and Bivalvia as in other parts of the world. The vertical distribution of each taxon can be summarized as follows.

1. *Fusulinacea*

Fusulinids are most important zone fossils of the Permian (Fig. 19). They are prolific in Unit 1, and then gradually decreased upward in number of species. Conspicuous events on the fusulinid history took place at the Unit 3/4 boundary and in the upper part of Unit 6. Nearly all the larger fusulinids disappeared at the end of Unit 3 and were replaced by smaller ones. For instance, the genera belonging to Verbeekinidae and Schwagerinidae are not found in the Abadehian and later excepting a sporadical occurrence of *Chusenella* sp. in Unit 4. Instead, species of Staffellidae (*Nankinella* and *Sphaerulina*) and the smaller fusulinids belonging to Schubertellidae (*Codonofusiella*), and Ozawainellidae (*Rauserella* and *Reichelina*) played an important role.

The second critical event is the extinction of all fusulinids at the end of the *Araxoceras tectum* Subzone in Unit 6. The first event corresponds to the lithofacies change from the limestone facies of Unit 3 to the terrigenous mud facies of Unit 4, and the second event from the open lagoonal sea to the restricted lagoonal one. It is noteworthy, however, that the first dramatic change took place nearly simultaneously over the world. This means that it is related not only to local environmental changes but to universal factors.

2. *Smaller Foraminifera*

Nearly all the Iranian foraminifers are benthonic. They are among the most prosperous Permian invertebrates. They were most diverse in the middle Abadehian age (Unit 4b), but declined remarkably in the Dzhulfian (Unit 6), and disappeared at the beginning of the Dorashamian (Unit 7) (Fig. 18). Comparable faunal changes of Foraminifera are observed in Chanakhchin and lower Araks Formations of Northern Caucasus (REITLINGER, 1965) and upper Murgabian and Dzhulfian of Antalya, Turkey (LYS & MARCOUX, 1978).

The stratigraphic distribution has a negative correlation with that of Fusulinacea suggesting an ecological replacement related to the lithofacies change. It is noteworthy, however, that the smaller foraminifers also flourished in the equivalent of Abadehian limestone facies in Pakistan, that is, the Kalabagh Member and the lower part of the Chhidru Formation (NAKAZAWA & KAPOOR, 1975), too. It seems that the vertical biological changes in the Abadeh were not local but wide

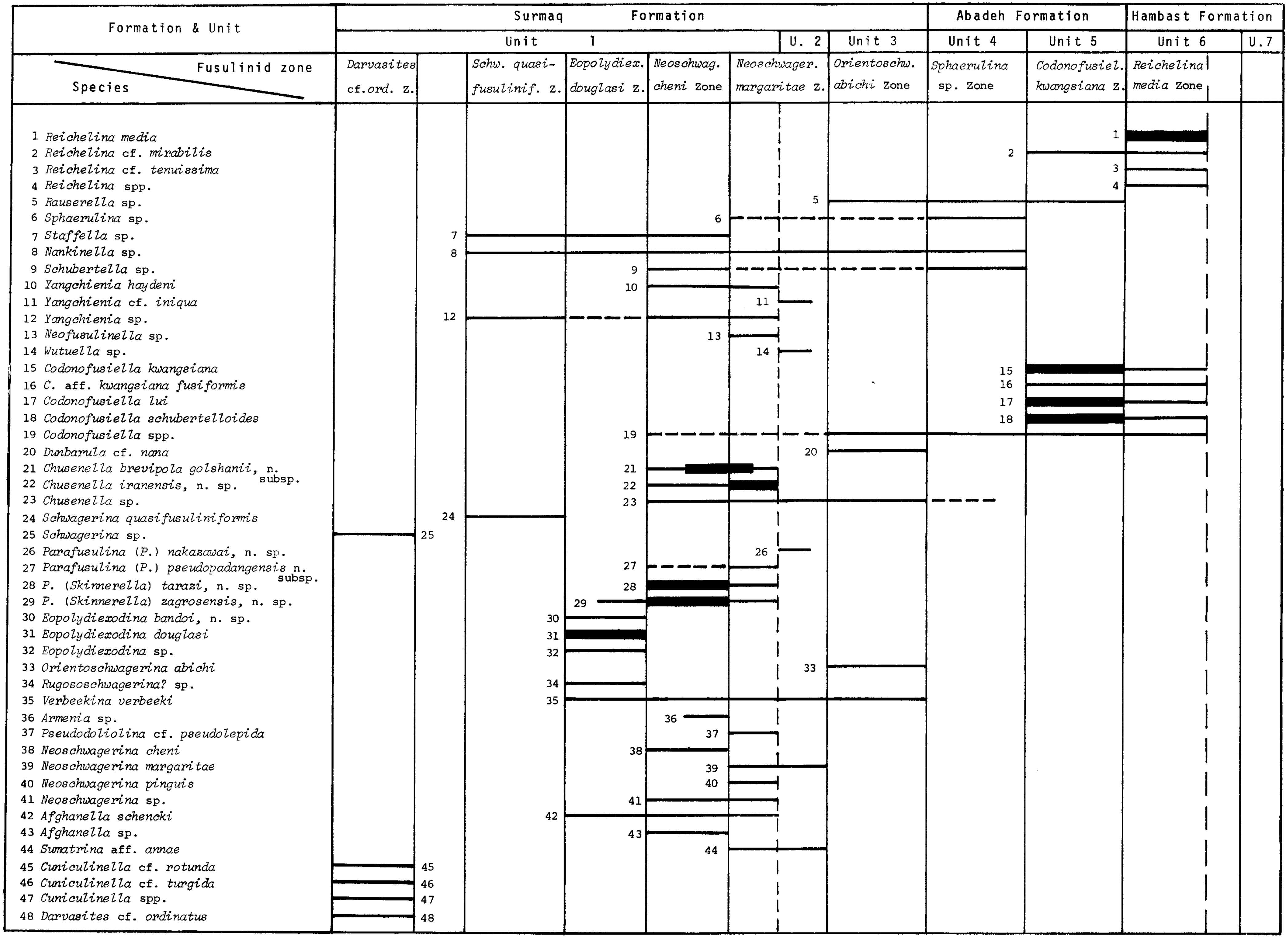


Fig. 19. Range-chart and zones of fusulinids.

spread.

Generally speaking, foraminifers of Units 1 to 3 are dominated by palaeotextulariids and small forms of *Pachyphloia* and *Globivalvulina.* On the other hand, the Abadehian age is characterized by a sudden increase of fisherinids and ammodiscids, and the development of large forms of *Pachyphloia* and *Globivalvulina.* On the contrary, only a few small forms, such as *Nodosaria minuta,* n. sp. and *Glomospirella shengi* survived into the late Dzhulfian.

Concerning the geographical distribution, collaniellids occur extensively in the Tethyan province and are important for international correlation. *Robuloides* and *Lasiodiscus* also have a wide distribution, but are not common as individuals. From present available data, the *Hemigordiopsis-Paradagmarita-Globivalvulina vonderschmitti* assemblage is limited to the Middle East Province and is considered to be a characteristic fauna of that area.

3. *Anthozoa*

In general, corals are not very common in the Permian of Iran, but abundant at some horizons or at places; for example, solitary rugose corals are fairly common in Dzhulfa beds in Julfa region. They are important in considering the environmental conditions. In Abadeh region, corals are rather common in Units 1, 3 and 4, but rare in Units 2 and 6, and no corals have been obtained from Units 5 and 7. Thus corals declined upward throughout the Permian sequence at Abadeh. Corals collected from Abadeh and Julfa of Iran were examined by M. KATO of Hokkaido University, and the results are summarized below.

Only colonial corals have been provisionally identified. They are shown in Fig. 20 which includes seven species of Tabulata and seven species of Rugosa. Solitary corals need further studies, but the presence of such genera as *Lophophyllidium, Plerophyllum, Pleramplexus* and *Ufimia* are noted. Especially noteworthy is *Lophophyllidium,* which is confined within Unit 1 at Abadeh.

Looking through the overall stratigraphic distribution of coral assemblage in Abadeh and Julfa, though precursory, it is clear that massive, colonial rugosa disappears first in the lower sequence, followed by fasciculate forms, and then by solitary forms. Namely, massive, colonial rugose corals, such as *Ipciphyllum,* are present until Unit 3 of Abadeh region and the Gnishik beds in Julfa. Fasciculate (dendric) corals as *Waagenophyllum* continue up to Khachik beds, whereas solitary rugose corals extend up to Unit 6 in Abadeh and Dorasham beds in Julfa.

Several possible reasons may account for this change in growth form of corals, such as 1) the deepening of the sedimentary basin, 2) the shallowing of the basin, 3) the cooling of sea water, and 4) the decrease of salinity. The second case may have been responsible for the above-mentioned change in corals, judged from the sedimentological analysis, but in the case of Unit 6, the decrease of salinity may be a possible cause.

Coral species	Abadeh						
	1	2	3	4	5	6	7
Tabulata							
Michelinia favositoides Girty	*						
Michelinia sp.	*						
Michelinia abnormis Huang						---	
Michelinia multitabulata Yabe et Hayasaka	---	---	---				
Michelinia microstoma Yabe et Hayasaka	---	---	---				
Michelinia laosensis Mansuy				*			
Sinopora asiatica (Mansuy)	* ---	---	---				
Rugosa							
Yatsengia hangchowensis Huang	*						
Lonsdaleiastraea or *Wentzelellites* n. sp.?			*				
Waagenophyllum kueichowense Huang	*?			---	---	*?	
Ipciphyllum laosense (Patte)	*						
Ipciphyllum simplex Wu		*—	—*				
Ipciphyllum flexuosum (Huang)			*				
Wentzelophyllum cf. *jenningsi* (Douglas)	---	-?-	---				
	Gnishik			Khachik		Dz	Dr
	Julfa						

Fig. 20. Occurrence of colonial corals of the Permian in Abadeh (asterick) and Julfa (broken line). Dz: Dzhulfa beds, Dr: Dorasham beds.

4. *Brachiopoda*

Brachiopoda are among the most common benthonic macrofossils of the Permian. They reached the height of prosperity in the upper part of Unit 1, then gradually decreased with a pattern of vertical distribution similar to that of the Fusulinacea (Fig. 20), but Brachiopoda did not experience such a dramatic change as in affected the Fusulinacea at the boundary of Units 3/4.

Some species had a long life interval ranging from Unit 1 through Unit 6 or 7. Examples are *Spinomarginifera spinosocostata*, *S. helica*, and *Orthothetina peregrina*. Strophalosiacea, Spiriferidina, Terebratulidina, Athyridina and Productidina are principal elements of Unit 1. The first three groups gradually declined, but the last two, together with Davidsoniacea (mainly *Orthothetina*), and *Leptodus*, were dominant in Unit 4 and later. Among the genera of Athyridina, *Spirigerella* and *Composita* were replaced by small *Araxathyris* and *Septospirigerella*, and large forms of Productacea (*Linoproductus* and *Vediproductus*) by *Tyloplecta* and *Araxilevis*.

A remarkable decline in brachiopods is recognized in the lower part of Unit 6

	Horizon	Surmaq Formation				Abadeh Format.			Hambast Fm.		
		Unit 1		U2	U3	Unit 4		U5	Unit 6		U 7
	Species	Low.	Upp.			Low.	Upp.		Lw.	Up.	
1	*Obginia dzhagrensis* Sarytcheva	*									
2	*Neochonetes armenicus* Sokolskaja	*									
3	*Phricodothyris asiatica* (Chao)	*	—	—	—	*					
4	*Krotovia jisuensiformis* Sarytcheva	*	*	—	—	*					
5	*Crenispirifer* sp. A	*	*	—	*						
6	*Edriosteges poyangensis* (Keyser)	*	*								
7	*Edriosteges* sp.	*	*								
8	*Richthofenia lawrenciana* (De Koninck)		*	—	*						
9	*Orthotichia avushensis* Sokolskaja		*								
10	*Orthotichia peregrina* (Abich)		*	—	—	—	—	—	*		
11	*Orthotichia* cf. *vediensis* Sokolskaja		*								
12	*Meekella arakeljani* (Sokolskaja)		*								
13	*Linoproductus lineatus* (Waagen)		*								
14	*Liostella magniplicata* (Huang)		*	—	—	*					
15	*Spinomarginifera jisuensis* (Chao)		*								
16	*Vediproductus vediensis* Sarytcheva		*								
17	*Wellerella arthaberi* (Tschernyschew)		*								
18	*Stenoscisma* aff. *pinguis* (Rothpletz)		*								
19	*Spirigerella timorensis* (Rothpletz)		*								
20	*Spirigerella subtriquetra* Ching et Liao		*								
21	*Avonia* sp. A		*								
22	*Araxthyris yunanensis* Yang		*								
23	*Martinia warthi* Waagen		*								
24	*Notothyris nucleosus* (kutorga)		*								
25	*Notothyris pseudojoulfensis* Licharew		*								
26	*Dielasma elongata* Schlotheim		*								
27	*Composita subtriangularis* (Reed)		*								
28	*Trigonotreta* sp.		*								
29	*Phricodothyris indicus* (Waagen)		*								
30	*Phricodothyris* sp. A		*	—	*						
31	*Chonostegoides armenicus* Sarytcheva		*	—	*						
32	*Spinomarginigera spinosocostata* (Abich)		*	—	—	*	—	—	*		
33	*Spinomarginifera helica* (Abich)		*	—	*	*	*	—	*	*	*
34	*Martinia corculum* Kutorga		*								
35	*Leptodus* sp. A				*						
36	*Orthothetina iljinae* Sokolskaja				*						
37	*Cryptospirifer iranica* n. sp.				*						
38	*Martiniopsis* sp.				*						
39	*Orthothetina* sp. A					*					
40	*Spinomarginifera ciliata* (Arthaber)					*					
41	*Uncinunellina sino-iranica* n. sp.					*					
42	*Spiriferellina hochuanensis* Liao					*					
43	*Orthothetina dzhulfensis* Sokolskaja					*	—	—	*		
44	*Leptodus nobilis* (Waagen)					*	—	—	*		
45	*Tyloplecta yangtzeensis* (Chao)					*	—	—	*		
46	*Tyloplecta tarazi* n. sp.					*	—	—	*		
47	*Orthothetina* sp. B						*				
48	*Spinomarginifera lopingensis* (Kayser)						*				
49	*Orthothetina regularis* Huang						*				
50	*Septospirigerella megridagina* Grunt						*				
51	*Septospirigerella baissalensis* Grunt						*				
52	*Crenispirifer* sp. B						*				
53	*Phricodothyris* sp.						*				
54	*Orthothetina* cf. *persica* (Schellwien)							*	*		
55	*Orthothetina eusarkos* (Abich)								*		
56	*Spinomarginigera pygmaea* Sarytcheva								*		
57	*Araxilevis intermedius* (Abich)								*		
58	*Araxathyris araxensis* Grunt								*	*	
59	*Araxathyris minor* Grunt								*	—	*
60	*Leptodus* sp. B								*	*	*
61	*Notothyris* aff. *nucleolus* (Kutorga)										*

Fig. 21. Simplified stratigraphic occurrence of brachiopods. The lower horizon of Unit 4 is located at the base of Unit 4b, and Unit 4a has no brachiopods excepting a single occurrence of *Cryptospirifer iranica* from the lower part.

as in other benthonic animals. A few dwarf forms, such as *Spinomarginifera helica*, *Araxathyris araxensis* and *Leptodus* sp., survived into later stages.

The brachiopod fauna as a whole is allied to that of Transcaucasia in the following respects. a) Inarticulata are absent, b) Davidsoniacea are represented only by Meekellidae, especially *Orthothetina*, c) Spiriferida are represented by Athyridina but rare in Spiriferidina, especially ribbed ones, and d) Terebratulida are poorly represented.

5. *Ectoprocta (Bryozoa)*

Bryozoans are not common throughout the Permian and they are absent in the Lower Triassic. Fifteen species of seven genera are recognized (SAKAGAMI, 1980). They were collected from Units 3 and 4 and the lower part of Unit 6 (the *Araxilevis* beds). Among them five species were originally described from Armenian Dzhulfa beds, two from the Salt Range, Paksitan, two from the Russian platform, and one from South China.

6. *Bivalvia*

Bivalves were scarce throughout the Permian. They are Abadehian *Myalina* (*M.*) sp., *Aviculopecten* sp. A, *Pseudomonotis* sp., "*Pteria*" sp. and an indeterminable species; and Dzhulfian *Aviculopinna* sp. The explanation of scarcity of Bivalvia is uncertain, but in the Julfa region nine species (*Parallelodon* sp., *Promytilus* sp., *Aviculopecten* cf. *malayensis*, "*Entolium*" sp., "*Streblochondria*" sp., *Wilkingia* sp., *Limipecten*? sp., *Sanguinolites* sp. and *Astartella* sp.) have been collected from the *Verbeekina-Chusenella* Zone, and four species (*Aviculopecten* sp., "*Entolium*" sp., "*Streblochondria*" sp., and *Crenipecten*? sp.) from the *Chusenella* Zone (unpublished data). In addition, four species, *Aviculopecten* sp., *Palaeolima*? sp., *Aviculopinna* sp., and *Schizodus* sp., are obtained from the Dzhulfa beds.

Claraia plays a leading role among marine invertebrates of the earliest Triassic at Abadeh. The absence of other kinds of bivalves may indicate deep waters in this area.

7. *Ammonoidea*

Ammonoids are confined to Units 6 and 7 where they are the most important zone fossils of the Late Permian, except for the occurrence of *Xenodiscus muratai* at the top of Unit 1 and *X. carbonarius* and *Cyclolobus* sp. from the basal part of Unit 4b. As stated already, Unit 6 contains species of Araxoceratidae and Unit 7 bears Xenodiscidae and Dzhulfitidae. These faunas are almost identical with those of Julfa and Transcaucasia.

Restricted lagoonal conditions with supposed fresh-water influx is postulated for the upper part of Unit 6, and for Unit 7 from the sedimentological study. This may suggest an inflow of ammonoid shells from the open sea. The abundant occurrence of these fossils may be explained by starved deposition. The combined thickness of Units 6 and 7 is only 35 m. In contrast to this, the correlative beds attain several hundred metres in South China (ZHAO *et al.*, 1978a) and more than 1,000 m in Northeast Japan (Working Group for Permian-Triassic Systems, 1975; EHIRO & BANDO, 1980). Some of ammonoid shells in Julfa region are burrowed by worms (Pl. 6, Figs. 3a, b), and some are attached by echinoids (Pl. 6, Fig. 4). These facts also suggest a low depositional rate of the uppermost Permian strata. Red color of Dorashamian limestones may also be attributed to submarine oxidation during the slow deposition as was concluded for the Jurassic limestones of DSDP Legs 43 and 44 (MURDMAA, 1978).

Aside from *Xenodiscus*, all the Permian genera were extinct before the end of the Permian, and the Lower Triassic sea was occupied by ophiceratid ammonites derived from xenodiscids.

8. *Conodontophorida*

Rock-samples older than Unit 4b have not been treated for conodonts. Conodonts are rare in Unit 4b, but common in, and above Unit 5. The genus *Gondolella* is important in the Permian, but replaced by the genus *Anchignathodus* at the beginning of the Triassic, which is in turn followed by *Neospathodus* (Fig. 22).

Anchignathodus typicalis (*minutus* of authors) has a long range covering the interval from Unit 4 into the basal part of the Lower Triassic. The occurrence of the Permian *Gondolella orientalis* and *G. subcarinata* in the Lower Triassic at Section H is not certain; they may be relict or secondarily derived. Anyway, Conodontophorida and Ammonoidea were less affected through the Permian-Triassic crisis than other taxa.

Looking through the species ranges, it is evident that the greatest faunal change took place at the Permian-Triassic boundary. Species of benthonic animals did not cross the boundary. A small foraminifer, *Glomospirella shengi* Ho was reported from the Lower Triassic in China but not found at Abadeh. *Xenodiscus* sp. of the Triassic is specifically separated from the Permian species.

Such remarkable changes, however, started in the Early Dzhulfian in relation to the environmental changes. The feature of rise and fall of organisms shows that it is combined with the local environmental change and mutual relation within a ecosystem, but also suggests that some universal factors originated in environmental change were responsible for the mass extinction at the end of the Permian.

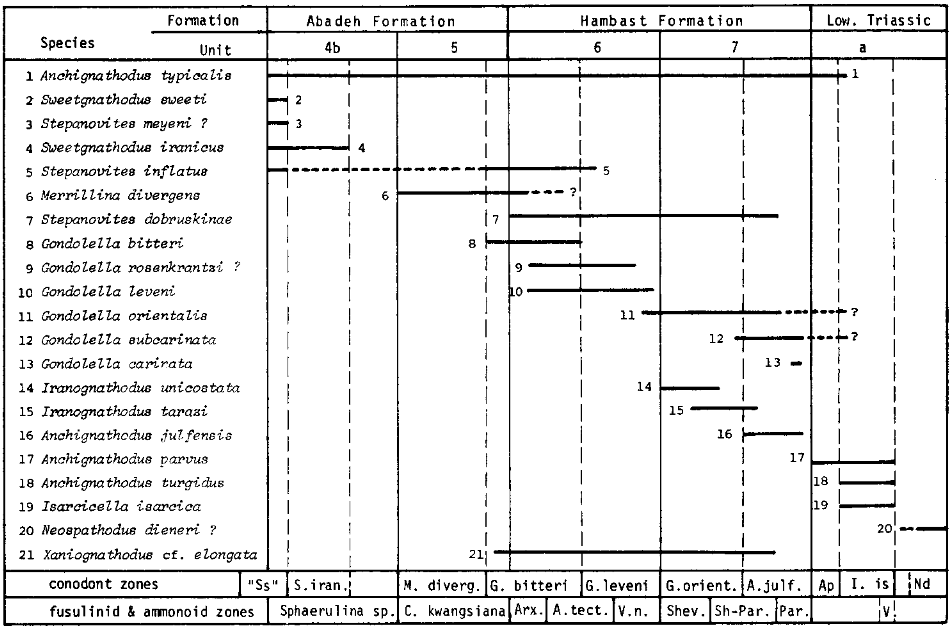


Fig. 22. Range-chart and zones of conodonts compiled from Sections A, C, H and HN.

X. Summary

Nearly continuous sedimentary sequence ranging from Artinskian up to the Middle Triassic are well documented in the Hambast Range, Abadeh region, Central Iran. The Permian and the lower part of the Lower Triassic were carefully examined paleontologically and sedimentologically. The Permian strata are lithologically divisible into seven units (Units 1 to 7) which can be grouped into three formations, namely, the Surmaq, the Abadeh, and the Hambast Formations, in ascending order. The main results are enumerated as follows.

(1) Eight fusulinid zones can be established in the interval from the base of the Surmaq Formation to the lower part of Unit 6 of the Hambast Formation, that is, Zones of *Darvasites* cf. *ordinatus*, *Schwagerina quasifusuliniformis*, *Eopolydiexodina douglasi*, *Neoschwagerina cheni*, *Neoschwagerina margaritae*, *Orientoschwagerina abichi*, *Sphaerulina* sp., *Codonofusiella kwangsiana*, and *Reichelina media*, and five ammonoid zones or subzones in the Hambast Formation, namely, the *Araxoceras tectum* Subzone and *Vedioceras nakamurai* Subzone of Unit 6 and the *Shevyrevites*, the *Shevyrevites-Paratirolites*, and the *Paratirolites* Zone of Unit 7. Seven conodont zones are also recognized in the Abadeh and Hambast Formations. They are Zones of *Sweetgnathodus sweeti*, *S. iranicus*, *Merrillina divergens*, *Gondolella bitteri*, *G. leveni*, *G. orientalis*,

and *Anchignathodus julfensis*, in ascending order.

(2) The correlation of the Permian in the Tethys province was attempted based on these various fossil zones taking the other kinds of fossils into consideration as well. As a result, it is concluded that the Upper Permian System may be classified into three stages, the Abadehian, the Dzhulfian, and the Dorashamian. The Abadeh Formation, the type of the Abadehian, is characterized by smaller fusulinids and diversified smaller foraminifers. It is correlated with the Khachik beds in Transcaucasia, the *Codonofusiella-Reichelina* beds in Pamir, the lower part of the Wujapingian Stage in South China, the *Lepidolina kumaensis* to *Stacheoceras* horizon in Northeast Japan and the Upper Wargal to the Lower Chhidru Formation in the Salt Range, Pakistan.

(3) The lower part of the Lower Triassic contains many bivalves identified as *Claraia radialis julfensis*, *C. extrema extrema*, *C. aurita*, etc. and ammonoid shells of *Vishnuites pralambha*, *Lytophiceras dubium*, *Acanthophiceras golshanii*, etc. which indicate Gyronitan or Late Griesbachian age.

Three conodont zones can be distinguished also in the lower part of the Lower Triassic, namely, the *Anchignathodus parvus*, the *Isarcicella isarcica*, and the *Neospathodus dieneri*? Zones. The *Vishnuites* horizon is included in the uppermost part of the *I. isarcica* Zone. Comparing with the conodont zones in Kashmir, the *A. parvus* Zone, which characterizes the lowermost part of the Triassic at Abadeh, can be correlated with the upper part of the *Otoceras woodwardi* Zone in Kashmir. The lower part of the latter zone is most probably missing here, and the Permian-Triassic relation is considered as a paraconformity. The emergence at the Permian-Triassic boundary is supported by the sedimentolological analysis, and the Dorashamian is concluded to be older than the Lower Griesbachian or Gangetian.

(4) The lithofacies and biofacies changes throughout the Permian show a megacycle of transgression and regression. The transgression which started in the Artinskian age submerged the Abadeh region under open neritic (Unit 1) to basinal (Unit 2) environments. Then gradual shallowing of the sea proceeded with some fluctuations from basinal to lagoonal through open neritic conditions. The uppermost Permian (Dorashamian) is characterized by intertidal or supratidal facies. Adjusted boron and lithium in the sediments decreased to the minimum in Unit 7, presumably caused by fresh-water inflow. Their low content in Unit 3 and Unit 4a are, however, difficult to explain.

The emergence at the end of the Permian is indicated by a paraconformable relation between the Permian and the Triassic. Rapid transgression is indicated by thin-bedded alternations of limestone and shale above thin stromatolitic beds, which exhibit an intertidal-subtidal episode. The alternations include some turbidites and abundant trace fossils of *Zoophycos-Chondrites* facies. They are considered to have been deposited on the deeper shelf by low density turbidity currents.

(5) The greatest faunal changes occurred at the Permian-Triassic boundary. Nearly all the organisms disappeared at or before the end of the Permian. This remarkable change started in the Dzhulfian. The rise and fall of each taxon reveals that the vertical change of organisms is related not only to the local environmental change and mutual relation within a ecosystem, but also to universal causes.

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Errata

page	figure	line	read	for
96–97	12	16	*vonderschmitti*	*conderschmitti*
113	15	Unit 3 of 3rd column	Fusulinid	Fisulinid
121	21	10	*Orthothetina*	*Orthotichia*
〃	〃	24	*nucleolus*	*nucleosus*
〃	〃	50	*megridagica*	*megridagina*

Explanation of Plate 1

Fig. 1. Distal view of the Upper Permian-Lower Triassic strata (from upper part of Unit 4a to Unit a) in Hambast Valley, where Sections C, CC, and CT were measured (looking west). B–0, –7, and –13 indicate Horizon numbers.

Fig. 2. Same exposure as in Fig. 1 showing type section of the Abadeh Formation (looking south).

Fig. 3. Exposure of upper part of the Surmaq Formation (Units 2 and 3), Section L, Hambast Valley.

Fig. 4. Close-up of the same showing wavy bedding of thin and thick-bedded limestone facies of Unit 3.

Fig. 5. Distal view of the Upper Permian-Lower Triassic strata, Sections A and B, Hambast Valley (looking east). The central cliff consists of Units 6, 7, and a.

Explanation of Plate 2

Fig. 1. Distal view of Units 2 and 3 of the Surmaq Formation, Section NR, Surmaq.

Figs. 2 and 3. "Nodular limestone" of Unit 6 of the Hambast Formation, showing lenticular and wavy bedding, Hambast Valley (Section A).

Fig. 4. Flaggy shale and calcareous shale with thin-bedded limestone interbeds in the upper part of Unit 4b, Hambast Valley.

Fig. 5. Alternation of flaggy shale and limestone with chert nodule in the middle part of Unit 4b, Hambast Valley.

Explanation of Plate 3

Fig. 1. Intra-bioclastic limestone with sparry calcite cement, grain supported. Grains of irregular shape are randomly distributed. Hor. R–4, Unit 1 of the Surmaq Formation, Surmaq (Section NR).

Fig. 2. Calcitized monoaxonic sponge spicule biomicrite, intergranular mud supported. Sponge spicules are weakly oriented. Hor. L+3, Unit 2 of the Surmaq Formation, Hambast Valley (Section L).

Fig. 3. Recrystallized limestone characterized by clotted structure. Original texture is unknown. Hor. L+42, Unit 2 of the Surmaq Formation, Hambast Valley (Section L).

Fig. 4. Biomicrudite, intergranular mud supported. Grain size and constituent are fairly variable. Hor. L+77, Unit 3 of the Surmaq Formation, Hambast Valley (Section L).

Fig. 5. Biomicrite, intergranular mud supported. This limestone consists of various bioclastics. Hor. D–19, Unit 3 of the Surmaq Formation, Hambast Valley (Section D).

Fig. 6. Stromatolite with geopetal structure. Hor. C–0, Unit 4b of the Abadeh Formation, Hambast Valley (Section D).

Fig. 7. Formainiferal biomicrite, weakly recrystallized and mud supported. Hor. C–5a, Unit 4b of the Abadeh Formation, Hambast Valley (Section C).

Fig. 8. Algal biomicrite, intergranular mud supported. Hor. C–23h, Unit 4b of the Abadeh Formation, Hambast Valley (Section C).

(Scale bars in Figs. 1 and 7=1 mm, all figures same magnification.)

Explanation of Plate 4

Fig. 1. Well laminated algal biomicrite, grain supported. Almost all the elongate algal particles

are oriented parallel to bedding plane. Hor. C–17, Unit 4b of the Abadeh Formation, Hambast Valley (Section C).

Fig. 2. Weakly laminated algal biomicrite, grain supported. Platy algal fragments are oriented roughly parallel to bedding plane. Hor. C–13a, Unit 4b of the Abadeh Formation, Hambast Valley (Section C).

Fig. 3. Well laminated algal biomicrite with worm burrow, grain supported. Hor. C–14, Unit 4b of the Abadeh Formation, Habast Valley (Section C).

Fig. 4. Crinoidal biomicrite, grain floated. This is an exceptional example of Unit 6, for almost all the limestones are structureless lime mudstones. Hor. CC–4, lower part of Unit 6 of the Hambast Formation, Hambast Valley (Section C).

Fig. 5. Lime mudstone, partly grain floated. Wavy shell-section of lower center is trilobite. Hor. CC–12, Unit 6 of the Hambast Formation, Hambast Valley (Section C).

Fig. 6. Intra- or litho-micrite containing small foraminifers and thin shells of ostracod, grain ("mud-ball") floated. Hor. H–73, Unit 7 of the Hambast Formation, Hambast Valley (Section H).

Fig. 7. "Intramicrite" or lime mudstone having mud-ball structure. Hor. B–10, Unit 7 of the Hambast Formation (Section B).

Fig. 8. Lime mudstone having birds eye structure. Hor. B–24, Unit 7 of the Hambast Formation, Hambast Valley (Section B).

(Scale bars in Figs. 1 and 8=1 mm, all figures same magnification.)

Explanation of Plate 5

Fig. 1. Photomicrograph of massive thrombolite, Hor. C2, Section C, Hambast Valley.

Fig. 2. Photomicrograph of "vermicular limestone", Hor. C23, Unit a, Section C, Hambast Valley.

Fig. 3. Exposure of Permian-Triassic transition, Section C, Hambast Range a: Permian *Paratirolites* beds, b: pale greenish brown shale of the base of the Triassic, c: layered thrombolite, d: massive thrombolite, e: thin-bedded platy limestone.

Fig. 4. Polished surface of massive thrombolite showning texture.

Fig. 5. Exposure of alternation of limestone and chert, Unit 2.

Fig. 6. Photomicrograph of top of the Permian, showing mud crack. m: muddy part filling crack.

Fig. 7. Thin-bedded platy limestone above thrombolite beds.

Explanation of Plate 6

Fig. 1. Parallel-laminated limestone of Unit a. Section C, Hambast Valley.

Fig. 2. Photomicrograph of parallel-laminated limestone of Unit a, Hor. C14, Section C, Hambast Valley.

Fig. 3a. *Pseudogastrioceras abichianum* bored by unknown worm (L). *Pseudogastrioceras-Permophricodothyris* Zone (Dzhulfian), Kuh-e-Ali Bashi, Julfa.

Fig. 3b. Enlargement of quadrangle L of the preceeding.

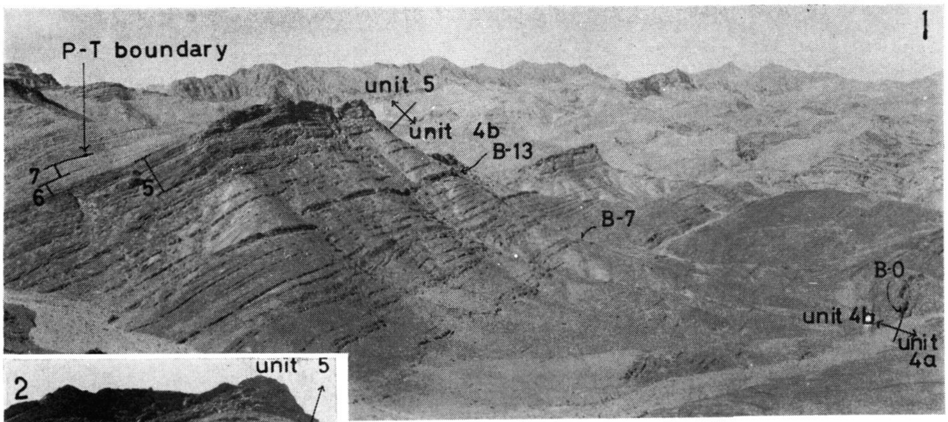
Fig. 4. Enlargement of attached part of echinoid on the surface of *Pseudogastrioceras*. Horizon and locality are same as in Fig. 3.

Fig. 5. *Chondrites* sp., *Claraia aurita* Zone of Unit a, Hambast Valley.

Fig. 6. *Megagrapton*-type trace fossils of Unit a, Hambast Valley.

Fig. 7. Bulbous flute moulds of Unit a, Hambast Valley. Arrow indicates paleocurrent direction.

Fig. 8. Crescent moulds of Unit a. Arrow indicates paleocurrent direction.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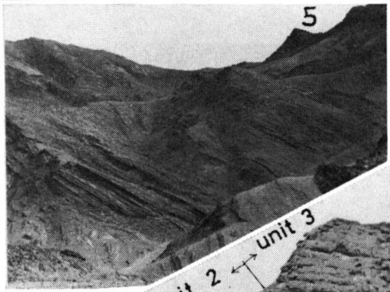
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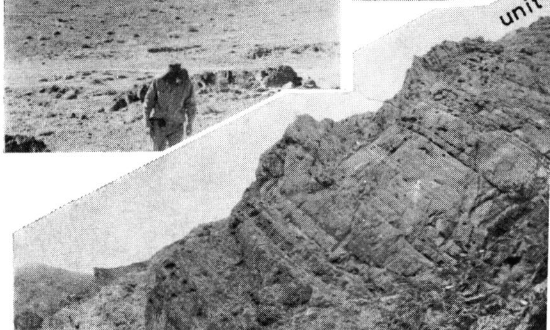
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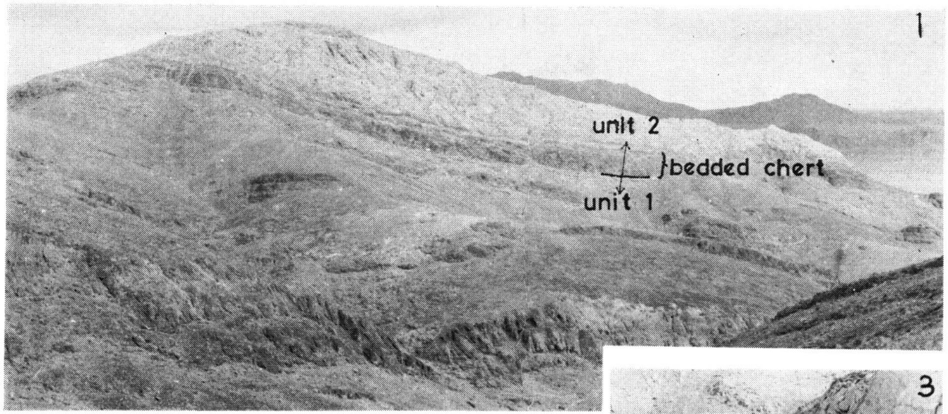
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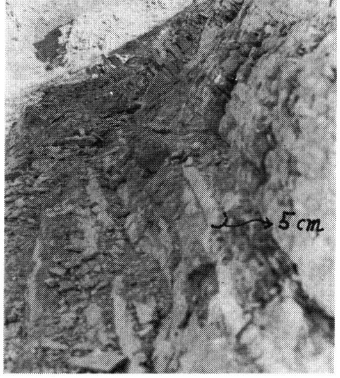
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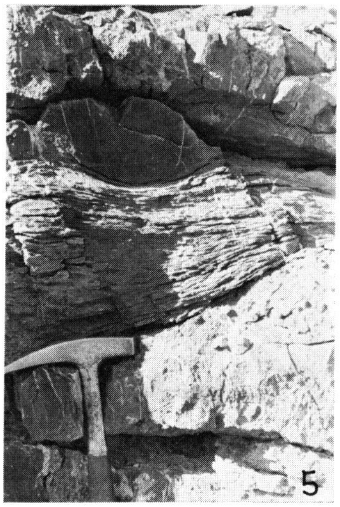
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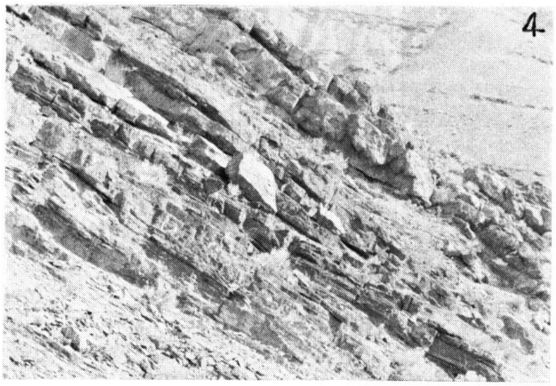
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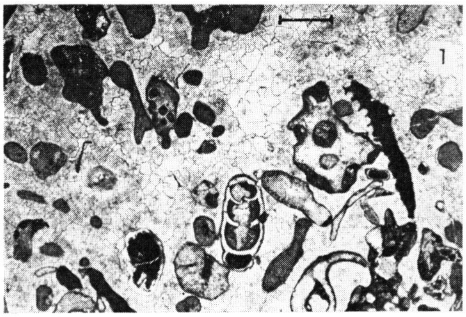
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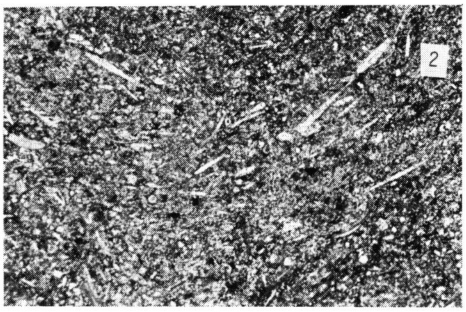
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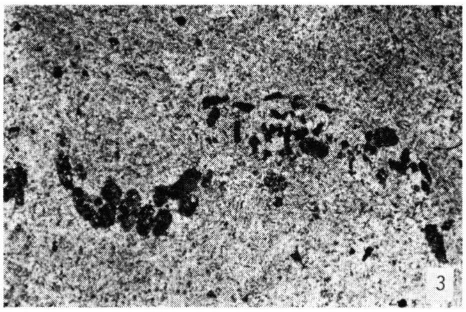
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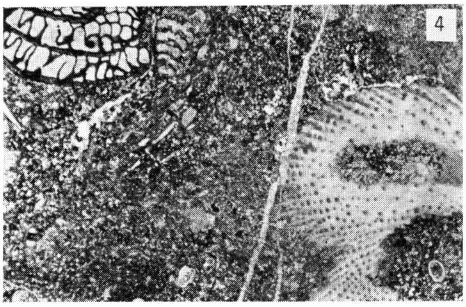
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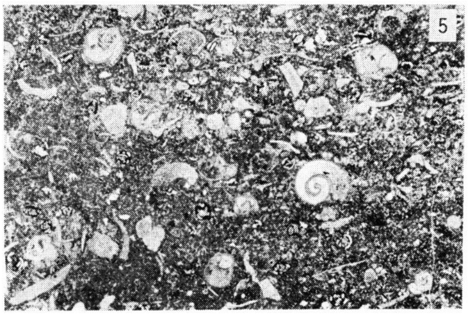
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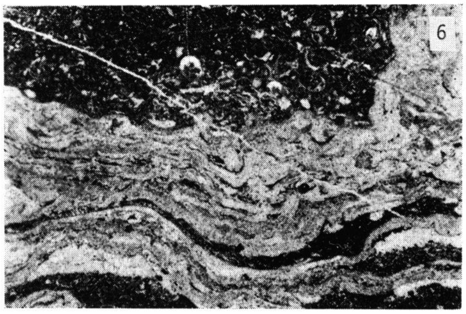
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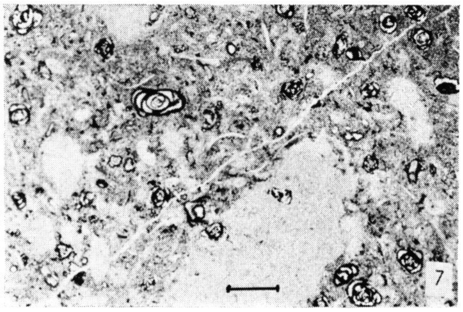
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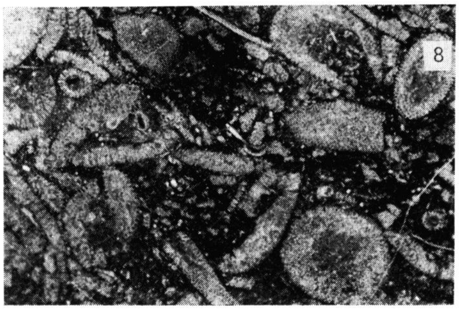
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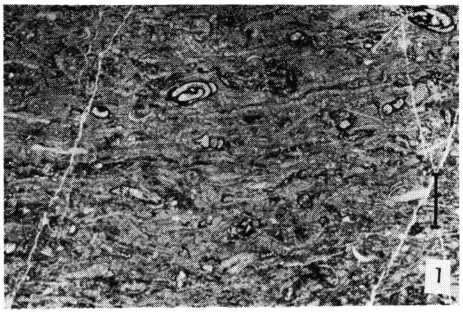
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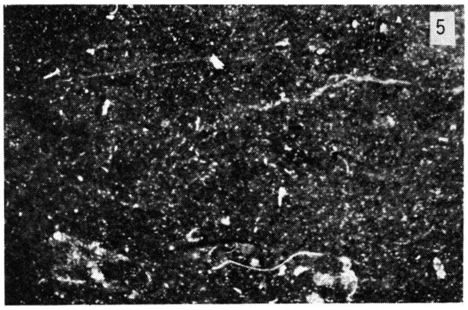
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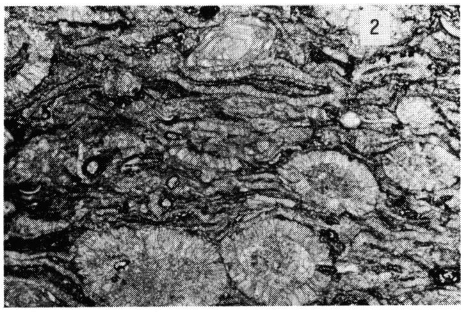
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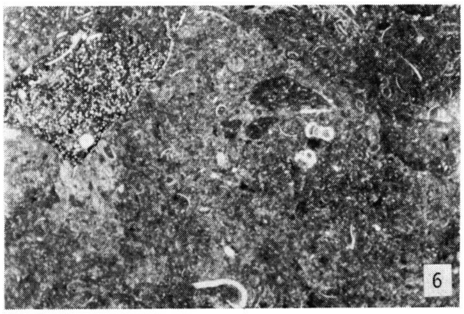
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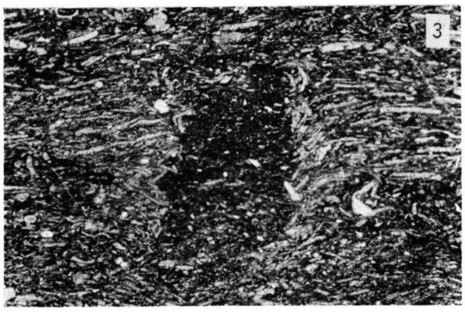
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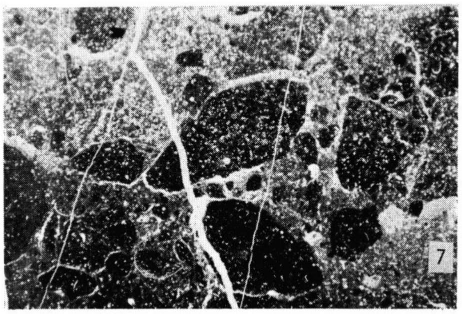
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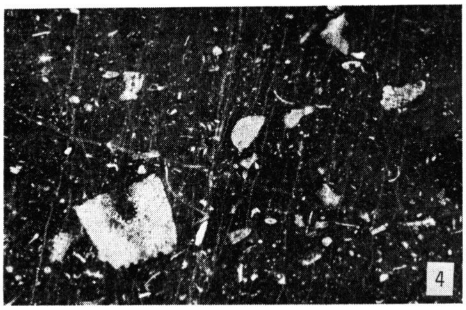
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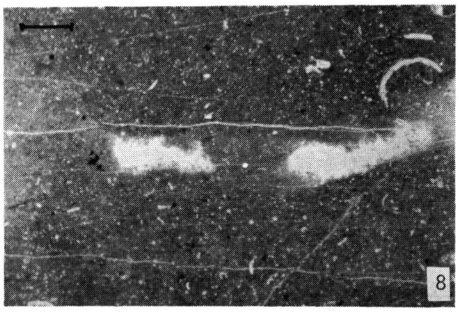
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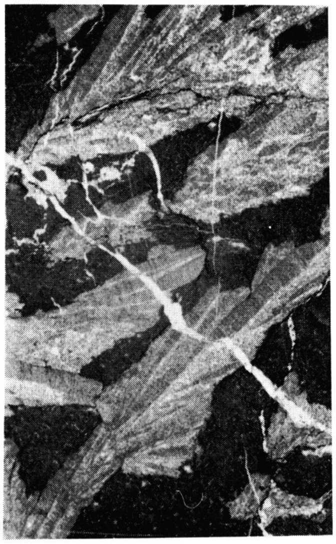
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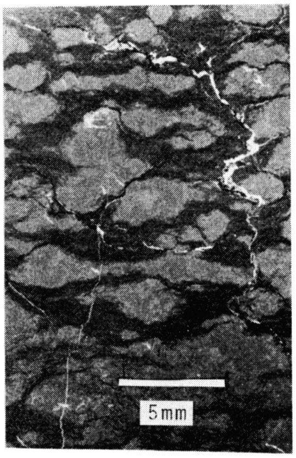

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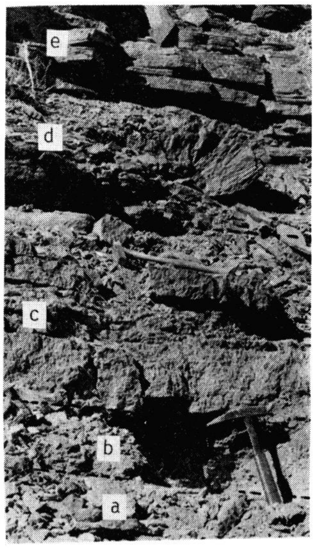

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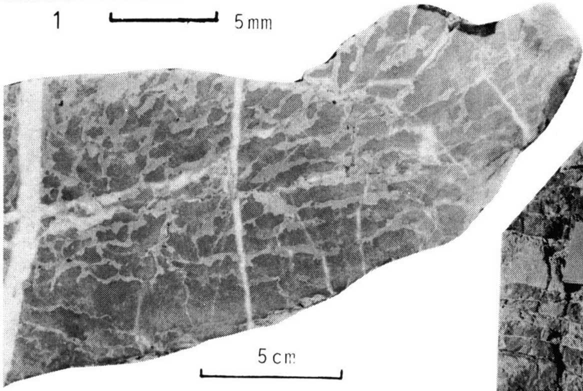

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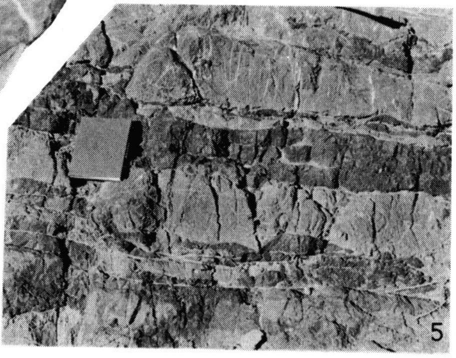
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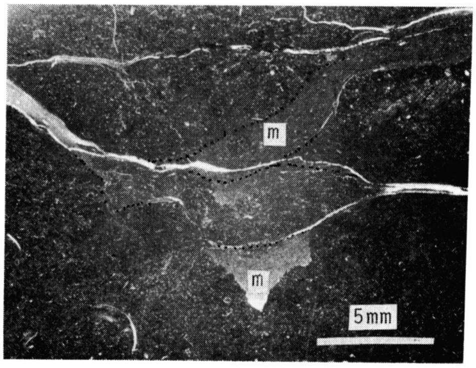


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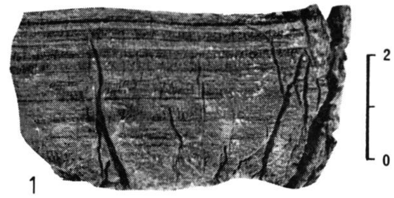
Iranian-Japanese Research Group: Permian and Lower Triassic in Abadeh, Iran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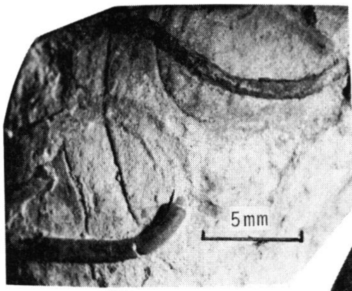
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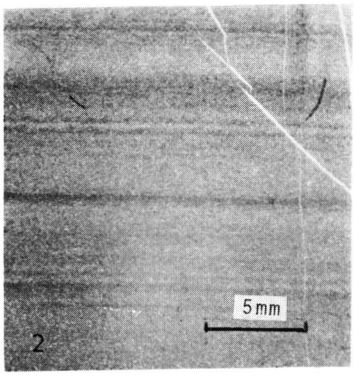
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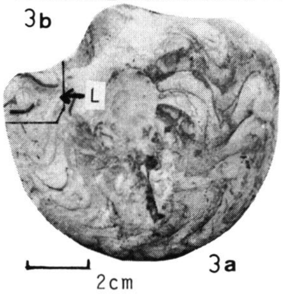
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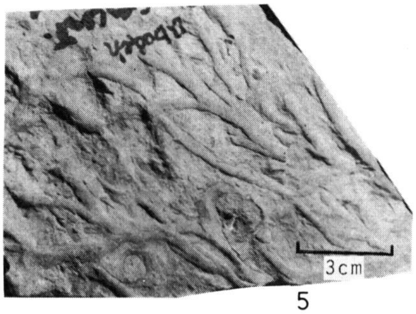
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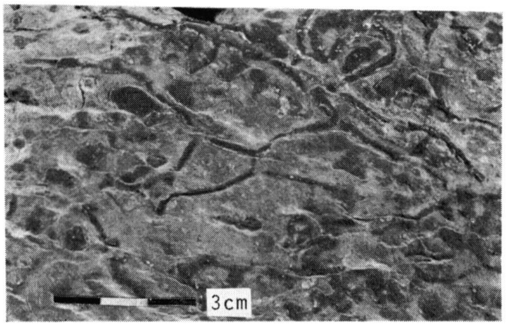
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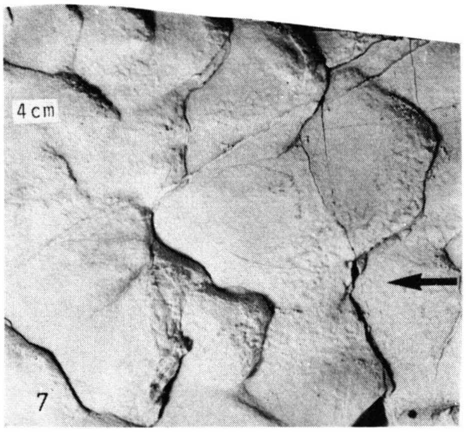
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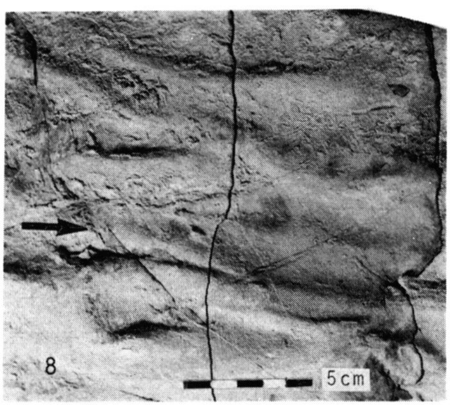
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