The Mesozoic of Afghanistan

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ABSTRACT

This paper is a review of the geology of the widely distributed Mesozoic rocks of Afghanistan. The country is a mosaic of structural blocks in a variety of geodynamic settings that were juxtaposed during the evolution of the Tethyan Ocean; the Mesozoic sedimentary, volcanic, and plutonic rocks therefore differ greatly from one block to another. Because of the adverse security situation, fieldwork has not been possible since the late 1970s and the data used in this review are therefore relatively old but are the best available. Interest in the geology of Afghanistan remains strong due to its position between the mountain chains of the Middle East and the collisional ranges of the Pamirs and Himalayas. A special feature of Tethyan geodynamics is the presence of Cimmerian (latest Triassic to earliest Cretaceous) continental blocks, microcontinents, or terranes located between the Eurasian and Indian landmasses. They are fragments of Gondwana inserted between the Paleo- and Neo-Tethys during the Mesozoic. This complex part of the Tethyan realm is well exposed in Afghanistan where the effects of the Indo-Eurasian collision were less intense than in regions of frontal collision, such as the Pamir and Himalayan ranges. It is for this reason that Afghanistan is of particular geodynamic interest and a key region in the understanding of the genesis and evolution of the Tethyan system during the Mesozoic.

INTRODUCTION

At the beginning of the 1960s, knowledge of the geology of Afghanistan (Figure 1) was based principally on the results of a few remarkable pioneers (Griesbach, 1885, 1886; Hayden, 1911, and later, Furon, 1927). They provided the basic observations on the Mesozoic rocks that crop out in northern Afghanistan.

Subsequent geological exploration, for example Cizancourt et al. (1937), progressed slowly due to poor accessibility. Vast areas, in particular the large mountain massifs of central Afghanistan that are penetrable only with difficulty, still remain more-or-less unknown geologically. The extent of the knowledge at the end of this second period of exploration is given in the work of Popol and Tromp (1954), Desio (1960) and Mennessier (1961).

During the 1960s and the 1970s, international teams of German, Italian, French, and Russian geoscientists, working in collaboration with the Afghanistan Ministry of Mines, carried out more systematic research. Considerable progress was made in a relatively short time (for example, Weipert et al., 1970; Schreiber et al., 1972; Wittekindt and Weippert, 1973; Wittekindt, 1973; Dronov et al., 1973; Chmyriov et al., 1973; Abdullah et al., 1977; Abdullah and Chmyriov, 1977; Wolfart and Wittekindt, 1980; Afzali, 1982). Yet, despite the importance of the data produced during this period of intense scientific activity, countless hypotheses remain poorly supported given the complexity and multitude of the problems raised.

At the end of the 1970s, geological fieldwork was brought to a halt due to the deteriorating security situation and geologists could no longer search for answers to their questions in the mountains of Afghanistan.

The petroleum resources of Afghanistan were briefly documented by Bratas et al. (1970) and Akhmedzianov et al. (1973). More recently, they were the subject of a study made by a United States Geological Survey-Afghanistan Ministry of Mines and Industry Joint Oil and Gas Resource Assessment Team (Klett et al., 2007). A geology-based assessment method was used to estimate the undiscovered petroleum resources of northern Afghanistan, a prospective area of approximately
Figure 1: Schematic geotectonic map of Afghanistan.
86,000 sq km. Four petroleum systems were identified, subdivided into eight assessment units for the purpose of the resource assessment. The area with the greatest potential for undiscovered natural gas accumulations is in Upper Jurassic carbonate and reef reservoirs associated with thrust faulting and folding. The resulting mean estimates are 1.6 billion barrels (0.2 billion metric tons) of crude oil (range from 0.39 to 3.56 billion barrels), 16 trillion cubic feet (0.4 trillion cubic meters) of natural gas (range between 3.58 to 36.46 TCF), and 0.5 billion barrels (0.8 billion metric tons) of natural gas liquids (range between 126 and 1,325 million barrels). The potential for undiscovered crude oil is greatest in the Amu Darya Basin.

This paper presents the accumulated body of knowledge relating to the Mesozoic of Afghanistan with the aim of providing a starting point for future geologic exploration.

**PRINCIPAL PALEOGEOGRAPHIC AND STRUCTURAL DOMAINS OF AFGHANISTAN**

The geology of Afghanistan is dominated by several major shear faults that define a mosaic of blocks (Wellman, 1965). These faults, the Herat, Akhbaytal, Helmand, Hari Rud, Sarobi, and Chaman faults, reflect major lineaments (Figures 1 and 2) frequently containing ophiolitic complexes. In terms of modern tectonics, these lineaments are regarded as suture zones formed by successive collisions, mainly in the Mesozoic, between the Eurasian continental plate to the north and the southern terranes that resulted from the fragmentation of Gondwana.

A traverse across Afghanistan, from the Amu Darya River in the north to the mountain ranges of Pakistan in the southeast, shows the large, complex domain that separated the Turan Plate, the southern part of the Eurasian continent, from the Indian Plate before these collisions. Based on available evidence, this vast area of the Mesozoic Tethys is not a simple, homogeneous paleogeographic unit. Instead, it is composite, formed by the juxtaposition of various paleogeographic units. It has evolved in time, each of the composite domains changing throughout the Mesozoic. From the northern border of Afghanistan toward the southeast, the following units can be distinguished (see Figure 1 for localities).

**Northern Afghanistan**

The Afghan Turkestan plains (Figure 1) are the surface expression of the Turan Plate, the southern margin of the Eurasian continent. They are bounded to the north by the Amu Darya endoreic river. The platform that underlies the Afghan Turkestan plains, part of the Hercynian Orogen of Central Asia, is not uniform. It was formed from several uplifted or depressed blocks (for example, the Band-e Turkestan horst; Lapparent and Stöcklin, 1972), as indicated by thickness and facies variations in the Mesozoic and Cenozoic cover (Abdullah et al., 1977).

The Eastern Hindu Kush belongs to the Hercynian Orogen that extends northeastward as the western Badakhshan and northern Pamir ranges (Figures 1, 2 and 3) (see for example, Slavin, 1974; Boulin and Bouyx, 1977; Desio, 1977; Desio et al., 1964; Kafarskiy et al., 1973; Stöcklin, 1977; Vlasov, 1977; Boulin, 1980, 1981). A more discontinuous western extension lies in the Paropamisus Mountains that extend westward, to the north of Herat. The Hercynian domain is cut off to the south by the Herat Fault that can be traced into Badakhshan as the Akhbaytal Fault.

The Herat-Akhbaytal faults are interpreted by authors such as Karapetov et al. (1975) and Stöcklin (1977) as the suture resulting from the closing of the Hercynian Paleotethys. The Hindu Kush Domain was affected by the Triassic-Jurassic Cimmerian tectonic and magmatic events (Figure 1; and see Figure 10a for main unconformity). Since the late Paleozoic, the western Hindu Kush has been the site of detrital carbonate sedimentation, but during the Mesozoic its axial part acted as a high that separated two different paleogeographic zones.
Band-e Bayan Block

Lying south of the Herat Fault, this forms a narrow west-trending zone through central Afghanistan (Figure 1). It was formerly the ‘middle Afghanistan geosuture’ of Abdullah et al. (1977), and the ‘Band-e Bayan horst’ of Slavin (1974). Little is known about the complex structure of this zone. It has a Proterozoic core analogous to that in the Central Mountains (see below) (Andritzky, 1971; Slavin, 1974). Lower Paleozoic calcareous and detrital sediments (Wittekindt, 1973) include a thick volcano-sedimentary series that contains the world-scale magnetite deposit of Hajigak. A peri-Gondwana Carboniferous series (Vachard, 1980) is present. These characteristics suggest a connection between the Band-e Bayan Block and the Central Mountains prior to the Mesozoic.

The Mesozoic succession correlates with a homologous series in the Farah Rud Basin where it forms the northern margin. Here the sedimentary deposits of the Koh-e Baba Range are up to 5,200 m thick and include Oligocene volcanics and large granitic plutons (Figure 2; see also Figure 6a).

Farah Rud Domain

This is a largely Mesozoic basin lying between the Band-e Bayan Zone to the north, and the Central Mountains Block to the southeast, separated from the latter by the Helmand Fault (Figures 1, 2 and 6a). The basin received an extremely thick sequence (in excess of 10,000 m) of Mesozoic and Tertiary sediments and volcanic deposits. Schematically, the following units were identified by Blaise et al. (1978):

![Figure 2: View from space of Northern and Central Afghanistan (NASA Apollo 7); compare with Figure 1.](http://pubs.geoscienceworld.org/geoarabia/article-pdf/14/1/147/5444251/montenat.pdf)
(1) A poorly dated ophiolitic complex, probably Triassic in age, resulted from an oceanic opening of unknown magnitude between the Band-e Bayan and Central Mountains blocks.

(2) A sandy flysch in which Late Jurassic and Neocomian (early Cretaceous) beds have been identified.

(3) Early Cretaceous red molasse, volcanics, and neritic carbonates, with orbitolines and rudists. Younger marine calcareous deposits date from the Late Cretaceous. The thickness of the deposits attests to persistent, strong subsidence.

(4) A thick continental volcaniclastic Paleogene sequence completed the filling of the basin.

The Farah Rud Basin is fan-shaped, being narrow in the east and largely open to the west. East of the Chaman Fault, traces of the basin are lost. However, according to Karapetov et al. (1975), a Triassic ophiolite complex originally situated between the Central Pamir geologic unit (homologue of the Band-e Bayan Block) and the South Pamir (homologue of the Central Mountains) is evidence for the eastern continuation of the oceanic basin (Figure 1).

To the west, the structures of the Farah Rud Domain abut a north-south lineament, the Hari-Rud Fault, which more-or-less follows the line of the Afghan-Iran frontier; the basin does not have any direct continuation in Iran.

Central Mountains and their Equivalents

The zone is bounded by the Helmand and Chaman faults that converge northeastward at about the latitude of Kabul (Figures 1 and 2). To the southwest, the zone lies buried beneath the Seistan Desert. The Central Mountains is a continental block with a Proterozoic basement that was an integral part of Gondwana as demonstrated particularly by Eocambrian and Carboniferous to Lower Permian sequences (see Blaise et al., 1977, 1982; Montenat, Vachard and Termier, 1977; Vachard, 1980; Bordet et al., 1984).

During both the Paleozoic and Mesozoic, the Central Mountains region was a diversified platform on which the distribution of the subsiding troughs or emergent ridges appears to be linked to the reactivation of major pre-Paleozoic faults (Desparmet and Montenat, 1972). Yet, despite this relative mobility, no notable orogenic activity occurred from the Cambrian to the end of the Triassic. The first significant deformation took place during the Cretaceous with important magmatic events occurring during the middle Cretaceous (Figures 1 and 2).
The terms Median Mass or Central Domain, when applied to the Central Mountains, relate to the location of this cratonic block between the oceanic basins of northern Farah Rud and south Beloutch during at least part of the Mesozoic. In addition, the Cimmerian, and especially the Neocimmerian orogenies (Late Triassic to Early Jurassic), differ in their structure from the more southerly regions that were mainly affected by the Alpine Orogeny (Sborschikov et al., 1973). The Kandahar Basin formed along the southeastern margin of the Central Mountains during the Late Jurassic and Cretaceous.

The Central Mountains have no direct western extension in Iran beyond the Hari-Rud lineament, a feature common to the Band-e Bayan and Farah Rud domains.

Northeast of the angle formed by the junction of the Chaman and Helmand faults, it is probable that the paleogeographic and structural equivalents of the Central Mountains are present in the Wakhan and Nouristan regions of Afghanistan (Desio et al., 1968). These various elements were disrupted and displaced along shear faults during Tertiary orogenic activity (Karapetov et al., 1975; see also Sborschikov, 1976; Stöcklin, 1977; Blaise et al., 1977, 1982) (Figure 1).

**Southeast Afghanistan: Kabul Block and the Beloutch Ranges**

These regions to the east of the Chaman Fault (Figures 1 and 2) differ structurally from the area to the west. The Kabul Block is a triangular-shaped cratonic fragment. It is separated from the Central Mountains to the west by the Chaman Fault, and the Sarobi Fault to the east marks its boundary with Nouristan. To the southeast, it is bounded by the faults of the Altimour Chain that separate it from the Beloutch Ranges.

The Kabul Block has a Proterozoic metamorphic basement overlain by a carbonate sequence, the Khinguil Series, of Late Permian to Cretaceous age. The Permian rocks are closely related to those of the Central Mountains but, in contrast, the Mesozoic deposits become increasingly different with decreasing age. The Triassic allochthonous units (see below), other Mesozoic pelagic sediments, and ultramafic rocks are thrust onto the Kabul Block as the Kotagae Series and Logar peridotites (Mennessier, 1977; Cassaigneau, 1979; Tapponnier et al., 1981).

Most of the Beloutch Ranges, east of the Chaman Fault, are formed of Cretaceous and Paleogene flysch (Figures 1 and 4). Beneath this Tertiary cover, further to the east near Khost, are older Mesozoic units consisting of ophiolites and deep-water sedimentary rocks. These are better developed in Pakistan (Waziristan and Zhob) where they are thrust over the Indian Foreland.

**TRIASSIC STRATIGRAPHIC SUCCESSION**

Figure 5 summarizes of the Mesozoic succession in Afghanistan.

**Northern Afghanistan**

There are three principal areas of Triassic sedimentation, namely, the North Hindu Kush Rift, the Turkestan Flyschoid Basin, and continental deposits of the northern border.

**North Hindu Kush Rift**

The rift contains a thick series of marine volcano-sedimentary beds that crop out in a broad east-trending band about 100 km wide, forming the northern slopes of the Hindu Kush. Westward, it may continue north of Herat into eastern Iran. To the east from Dochi, the belt of Triassic rocks extends into the northern Pamirs (Vlasov, 1977). The Triassic is generally discordant on Permian marine limestone (near Doab), or continental red beds of the same age northeast of Herat.

Fault scarps fossilized by Triassic deposits (Boulin and Bouyx, 1977) reflect the penecontemporaneous tectonic extension that formed the North Hindu Kush Rift. The rift filled throughout the Triassic, but with variations in thickness, facies and local lacunae that indicate its structural complexity. The stratigraphic fill is best documented at the eastern and western ends of the rift. Numerous sections
have been described in the west in the Paropamisus Mountains north of Herat (Kulakov et al., 1969) and in the east on the northern slopes of the western Hindu Kush (Kolchanov et al., 1970a). The stratigraphic succession is summarized in Figure 5, and described as follows:

(1) Lower Triassic (0–2,000 m) felsic, intermediate, or mafic volcanics associated with conglomerates, sandstones, and argillites. These have yielded a fauna that includes *Eumorphotis multiformis* (Bitt.), *Myophoria cf. laevigata* (Ziet), *Naticella (Nathitia) ex gr. costata* (Mstr.), *Kashmirites* sp., *Tirolites* sp., northeast of Herat (Kulakov et al., 1969); *Claraia* sp. and ammonites near Doab (Boulin et al., 1979).

(2) The Middle Triassic (0–2,000 m) also consists of volcanics and detrital rocks, with argillaceous and calcareous units more common than in the underlying Lower Triassic sequence. Limestones with corals occur (Furon and Rosset, 1951; Abdullah et al., 1977). Fossils are relatively abundant and the following Anisian fauna have been recorded: *Sturia sansovinii* (Mojs.), *Spiriferina fragilis* (Schloth.), *Mentzelia koeveskalliensis* Boeck., *Tetractinella trigonella* (Schloth.) from Koh-e Davindor northeast of Herat (Kulakov et al., 1969). Faunal associations with a more Ladinian aspect occur near Doab (Furon and Rosset, 1951): *Ceratites afghanicus* Fur. and Ros., *Sturia sansovinii* (Mojs.), *Monophyllites cf. sphaerophyllus* Hauer, *Trachyceras* sp., *Daonella cf. moussonii* (Mer.), Ladinian *Daonella moussonii* (Mer.), *D. indicus* Bitt., *D. esinensis* (Sal.), *Hungarites mojsisovicici* Boeckh., *Mesocladiscites involutus* Farsan, *Procladiscites* sp. from Khinjan, northeast of Doab (Farsan, 1972a,b; 1975). Farsan (1979) noted the Germanic character of the bivalve fauna.

(3) The Upper Triassic, more than 2,500 m thick, is also a volcano-detrital sequence. Marine Carnian-Norian near Doab contain *Pseudomotis* sp., *Cladiscites aff. tolli* Diener, *Monotis aff. salinaria* Bronn., and M. *daonellaeformis* Kip. (Kolchanov et al., 1970a). The Rhaetian alone may exceed 1,000 m in thickness. Lava flows and breccias (basalts, andesites, and rhyolites) are well developed and are associated with continental deposits containing plant fossils; such as, *Baieria* and *Podozamites* Furon, 1927; Furon and Rosset, 1951).
| Northern Afghanistan | Band-e Bayan | Farah Rud | Central Mountains | Wakhan | Kandahar | Kabul Block | Khinguil Series | Altimour Series | Belutch Domain | Jalalabad |
|---------------------|-------------|-----------|------------------|--------|----------|-------------|-----------------|----------------|---------------|----------|
| Upper Cretaceous    |             |           |                  |        |          |             |                 |                | Limestones    |          |
| Albain Barremian    |             |           |                  |        |          |             |                 |                | Limestones    |          |
| Neocom. (Berriasian to Hauterivian) | | | | | | | | | Limestones |          |
| Upper Jurassic      |             |           |                  |        |          |             |                 |                |              |          |
| Middle Jurassic     |             |           |                  |        |          |             |                 |                |              |          |
| Lower Jurassic      |             |           |                  |        |          |             |                 |                |              |          |
| Upper Triassic      |             |           |                  |        |          |             |                 |                |              |          |
| Middle Triassic     |             |           |                  |        |          |             |                 |                |              |          |
| Lower Triassic      |             |           |                  |        |          |             |                 |                |              |          |
| Upper Paleozoic     |             |           |                  |        |          |             |                 |                |              |          |

**Figure 5: Mesozoic sequences in Afghanistan.**
The Upper Triassic is discordant on the underlying beds and may overstep onto the Paleozoic basement along the northern and northwestern margin of the rift in the Pul-e Khumri area north of the Hindu Kush (Kolchanov et al., 1970a).

To summarize, the deposits in the North Hindu Kush Rift are up to 6,000 m thick and are dominated by syn-rift terrigenous deposits together with considerable volumes of volcanic rocks (see Figure 28a) and subordinate carbonates. The basin had been filled by Rhaetian times and the closure of the trough was a prelude to a phase of compression that preceded the deposition of various continental plant-bearing beds.

**Turkestan Flyschoid Basin**

This basin extends over the northern margin of the North Hindu Kush Rift, particularly in the Band-e Turkestan Mountains (see Figure 28a). The sediments consist of an argillaceous-arenaceous flysch with carbonaceous beds along the northern and western borders (Slavin, 1971). They differ from those of the North Hindu Kush Rift by the rarity or absence of volcanics in a thinner sequence of less than 1,000 m. No beds older than Ladinian are known (*Daonella prima* Kipar; Bratas et al., 1970). The Carnian has been identified by the presence of *Halobia australica* Mojs., *Monotis* sp., and *Sirenites senticosus* Dittmar (Bratas et al., 1970). The upper part of the series is more calcareous and contains bivalves and ammonites with Norian affinities (Slavin, 1971). The Rhaetian stage has not been identified.

**Northern Border Continental Triassic**

North of the flyschoid basin, continental carbonaceous deposits occur. Red terrigenous sedimentary rocks in a borehole in northern Afghan Turkestan were partially assigned to the Upper Triassic. They extend from the valley of the Amu Darya to at least as far south as Mazar-e Sharif (Kolchanov et al., 1970a).

**Band-e Bayan Block and Axial Zone of the Hindu Kush**

**Band-e Bayan Block**

This is a region of reduced sedimentation or an emerged zone, as indicated by bauxitic horizons (Slavin, 1971). The block forms a high, separating the Hindu Kush Rift Zone to the north from the ophiolitic Farah Rud Basin to the south. The Central Pamir Domain, the probable equivalent of the Band-e Bayan Block, also shows evidence of emergence, with Lower Triassic bauxitic horizons and Upper Triassic plant-bearing units (Karapetov et al., 1975).

**Axial Zone of the Western Hindu Kush**

This area lacks Triassic deposits. The axial zone and the Band-e Bayan Block are parts of an emergent high underlain by Triassic granitic intrusions. In the Turkman Triassic flyschoid basin (see below), reworked material in the turbidites indicates a source to the north from an emergent Hindu Kush (Montenat and Vachard, 1980).

During the Triassic, calc-alkaline granodiorites were intruded into the axial zone of the western Hindu Kush (see Figure 1), for example, the granitoid mass of Salang Col (210–220 Ma) (Debon et al., 1978, 1987; Abdullah et al., 1977). Similar Triassic granitoid bodies occur in the Band-e Bayan Block.

**Farah Rud Ophiolitic Basin**

**Waras Ophiolitic Complex**

This complex forms a narrow band, never more than 100 km wide, in the southern part of the Farah Rud Domain along the margin of the Central Mountains Block (Figures 1 and 6a,b). It is separated from the latter by the south-southeast–dipping Helmand fault zone. The Waras Complex was named and described by Blaise et al. (1978), Bassoulet et al. (1980), Montenat et al. (1986) and Girardeau et al. (1989). The descriptions of Stazhilo-Alekscev et al. (1973), Wittekindt (1973), Karapetov et al. (1975) (for the Navzac series), Slavin (1974), and Abdullah et al. (1977), are related to the same unit. Two major lithological elements have been distinguished.
- Chaotically deformed ultramafic lenses, cropping out mainly along the Helmand Fault (Figure 6a). The most accessible outcrop lies northwest of Behsud on the Helmand River near to the Mola Yaqub Pass. Most of the peridotites are serpentinized, but harzburgite, lherzolite, or wehrlite have been identified (Girardeau et al., 1989).

- A volcano-sedimentary series several thousands of meters thick may represent the cover of subordinate tectonically detached ultramafic rocks. The intense deformation of the ultramafics suggests that they may have been incorporated into the lower part of the sedimentary succession as a mélange (Girardeau et al., 1989). A stratigraphic succession cannot be identified because of the intense faulting, folding, and variable metamorphism, but the following lithologies are present:

  - Rhythmic sandy-pelite, turbiditic.
  - Calcareous microbreccias (turbidites) with limestone.
  - Greenish mafic submarine volcanics (hyaloclastites, pillow lavas, spilites) (Figure 7a).
  - Thin, brown or gray radiolarites (<10 m thick) (Figure 7b).
  - Abundant olistoliths, ranging in size from hundreds of meters to kilometers, composed of light gray or cream-colored crystalline carbonates (Figure 7c). They may have undulose (stromatolitic) or ribbon banding, or be rich in bioclastic ghosts.

The facies resemble those in the Permian-Triassic of the Central Mountains Block. Some of the olistoliths near Dehkundi contain Late Triassic megalodonts (Abdullah et al., 1977). The olistoliths are commonly encased in mafic pyroclastic material.

The whole series is affected by metamorphism that increases in intensity from north to south toward the Central Mountains, from greenschist facies (Panjaw) to amphibolite and garnet grade south of Waras. The rocks in the most intensely deformed area in the south have been mistaken for Proterozoic metamorphics (Wittekindt, 1973; Slavin, 1974; Abdullah et al., 1977; Blaise et al. 1978). The progressive increase in metamorphic grade makes it possible to recognize the original lithologies; for example, alternating garnet-mica schist and quartzite (turbidites), chaotic crystalline limestone (olistoliths), thinly banded quartzites (radiolarites), amphibolites and serpentinites (volcanics).

The age of the Waras Ophiolitic Complex is poorly defined. According to Karapetov et al. (1975), the Navzac Series, approximately equivalent of the Waras Complex, should be assigned to the Upper Triassic, whereas Slavin (1974) suggests a late Paleozoic age for the lowermost part of the series. In the upper part of the Complex, limestone microbreccias contain reworked microfaunal associations, from bottom to top, of Late Triassic to Jurassic (?) age. Therefore, the age of the Waras Ophiolitic Complex ranges from Triassic (?) to Jurassic. It is clearly pre-Early Cretaceous (Figure 6b; see also Figure 23).

**Turkman Basin**

Lying west of Kabul, this basin is separated from the Farah Rud Basin by the northwest-trending Siah Sang Fault (Figures 1 and 6a). However, it probably belongs to the same major paleogeographic unit.

The ‘Haut Helmand’ Series of schist and quartzite are exposed in the Turkman Valley where they are more than 1,000 m thick (Lapparent et al., 1974) (Figure 6a; see Figure 24). They have been assigned either to the Carboniferous based on lithological comparison with dated units in the Central Mountains (Blaise et al., 1977, 1978), or to the Triassic-Jurassic on inferred paleontological grounds (Sborshchkov et al., 1973).

In the upper part of the basin fill, calcareous microbreccias (turbidites) overlain by radiolarites and greenschists contain a microfauna originally assumed to be of Permian age by Montenat, Vavhard and Termier (1977) and Blaise et al. (1978). However, a more detailed study of the calcareous microbreccias indicated microfaunas of various ages (Carboniferous and Late Permian) closely associated with Triassic microorganisms. The latter are believed to indicate the true age of the deposit since no forms younger than the Triassic Glomospirella sp., Austrocolonia (?) sp., Thaumatoporella sp., and Triasina sp. (Montenat and Vachard, 1980) have been found. The overlying radiolarites are probably also Triassic. The possibility that the underlying Haut Helmand schists and quartzites may be Permian to Carboniferous in age.
cannot be excluded. Among the reworked organisms, forms characteristic of the Carboniferous of the Hindu Kush and unknown in the Central Mountains indicate a northern source for the turbidites. The subsidence of the deep Turkman Basin against an emergent Hindu Kush may indicate the location of the northern margin of the Farah Rud Basin during the late Paleozoic and the Triassic.

**Eastern Continuation of the Farah Rud Oceanic Basin—the Rushan Pshart Zone**

The volcanic deposits of the Farah Rud Basin can be traced eastward as a narrow band of greenschist metamorphic rocks (prasinites) (Blaise et al., 1982) until truncated by the Chaman Fault to the west of Kabul (see Figures 1 and 2). These volcanic-derived metamorphic rocks of the Gardan Dewal shear zone (Blaise et al., 1982), probably also include rocks derived from the Panjaw Flysch (see below). According to Karapetov et al. (1975), the Farah Rud Series is also exposed as the Rushan Fshart Series in the Pamir Range, close to the northeastern frontier of Afghanistan, due to left-lateral displacement along the Chaman Fault (the Pamir-Afghan Fault of Karapetov et al., 1975).
Figure 7: Waras Ophiolite Complex:
(a) Vertically dipping and compressed pillow lavas south of Panjaw;
(b) Dark-colored radiolarites interbedded with volcaniclastics near Waras;
(c) Olistolith of recrystallized Permian (?) limestone within volcano-sedimentary deposits of the Waras Ophiolite Complex near Waras. (Hammer for scale (a) and (b) 35 cm long).
The Rushan Pshart Series (Figure 1) crops out in a discontinuous series of strongly compressed tectonic slices along the Rushan Pshart Fault (the northeastern extension of the Herat Fault) that separates the central Pamirs (= Band-e Bayan Block) from the southern Pamirs (= Central Mountains Block). It consists of several distinct and strongly tectonized lithostratigraphic units (Shvol'man, 1978; Pashkov and Shvol'man, 1979; Ruzhentzev and Shvol'man, 1981; Khain, 1984), the lowest of which consists of a Carboniferous to Lower Permian episialic terrigenous series. Deep-water sedimentation, represented by radiolarite, flysch, and allodapic limestone, first occurred in the Late Permian. The occurrence of large transitional basalt flows within the flysch may indicate a rifting event in the continental block. The same types of sedimentary and volcanic deposits occurred throughout the Triassic Period and are about 500 m thick. The large-scale intrusion of granodiorite occurred in the northern part of the Rushan Pshart Basin at the end of the Triassic and during the Early Jurassic. A flysch series, 700 m thick, consisting of pelagic cherts, sandstones, and Paleozoic carbonate olistoliths, was deposited during the Jurassic, particularly in the eastern Rushan Pshart Zone. Scarce remnants of oceanic lithosphere occur as tectonic slices at the southern margin of the zone.

Central Mountains Domain and its Equivalents

Central Mountains

Within the continental block of the Central Mountains, as delimited by the Helmand and Chaman Faults (Figures 1 and 2), the widely distributed Triassic is represented by remarkably thick (>1,000 m) platform carbonates that include widespread dolomites. They conformably overlie Upper Permian dolomitic carbonates dated at many locations as Djulfian (Vachard and Montenat, 1981). In contrast, toward the top of the sequence, the transition to the Jurassic is marked by a terrigenous clastic episode with marine interludes (Rhaetian in part) and by discordance that is evidence of Eocimmerian tectonic events.

It has been demonstrated by Montenat and Vachard (1980) that these calcareous deposits are not uniform, but were deposited on an easterly dipping carbonate ramp. Within the Central Mountains it is possible to distinguish two distinct areas of sedimentation linked by a transition zone as follows:

• In the west, in the Ghizao-Aw Paran region (Figure 1), a northeastly trending zone characterized by an abundance of stromatolites and algal mats, as well as edgewise conglomerates and loferitic breccias at all levels, is indicative of a tidal-flat environment (Figures 8 and 13). The balance between shallow-water sedimentation and subsidence rates for about 20 Ma is remarkable, as is the total absence of evaporites. More open-marine conditions, with foraminifera, such as *Glomospira*, *Glomospirella*, and *Involutina*, probably represent short intervals of more rapid subsidence. The foraminifera identify rocks of Early Triassic and Middle Triassic (Anisian and Norian) age (Montenat and Vachard, 1980).

• The transition zone can be demonstrated by means of sections measured south of Behsud. The Anisian has yielded a bivalve faunule; for example, *Parallelodon hausmanni* (Dunk.), *P. esinensis* (Stop.), *Unicardium ventricosa* (Dunk.), *Pseudomyoconcha gastrochaena* (Dunk.), and *P. goldfussi* (Dunk.), with a characteristically Germanic aspect that raises an interesting paleobiogeographic problem (Farsan et al., 1982) (see Paleogeographic Evolution, p. 186). The stromatolithic and algal-mat formations (see above) are well developed in rocks of Anisian to Norian age.

• Typical external platform marine deposits without stromatolitic units occupy the eastern part of the Central Mountains. The Lower Triassic consists of marly *Claraia* limestone west of Mokur (Karapetov et al., 1971) and near Maleston (Marr, 1977) and nodular dolomitic limestone with ammonites *Columbites parisianus* H. and S., *Anakashmirites nivalis* Dien., *Flemingites pulcher* Welt., *Tirolites* sp., and *Dierococeras* sp. (Kadjoa Valley) (Blaise et al., 1977). The Middle Triassic is represented by vermicular limestone with spicules, radiolaria, rare *Glomospirella*, and traces of indeterminate ammonites. The vermicular, open-marine limestone extends into the Norian as dated by foraminifera near Wardak (Lys and Marin, 1973).
Neither the Ladinian nor Carnian stages have been identified in the three regions, although there is no reason to assume their absence. The facies distribution shows that the Triassic platform of the Central Mountains was tilted to the east in the direction of the open sea, as shown by the eastward development of ammonites, pelagic molluscs, and vermicular limestone. This eastward deepening was probably controlled by basement fractures; it is significant that the transitional facies occurs in the Behsud area, in the region of the Kadjao Fault that was active during the Paleozoic and throughout the Mesozoic (see Figure 28a) (Montenat and Bassoullet, 1983).

During the Rhaetian, there was homogenization of sedimentation conditions and the general extension of limestones with Involutines (foraminifera) and Megalodonts (pachyodont bivalves); for example, *Megalodon* sp., and *Dicerocardium* ex gr. *jani* Stop. (Lapparent and Sornay, 1968; Montenat and Vachard, 1980) present throughout the Central Mountains. It is probable that the Megalodont-bearing olistoliths incorporated into the Waras Ophiolitic Complex were derived from the erosion and fragmentation of the western margin of the Central Mountains carbonate platform.

Mafic intrusions of modest dimensions (on a scale of meters to tens of meters) are intrusive into Triassic stromatolitic dolomite in the western part of the platform (Ghizao region). They are always altered, serpentinized, or epidotized. However, olivine basalts have been identified that differ from volcanic rocks (mainly andesites) in the Lower Cretaceous of the same region (see below, Triassic of the Kabul Block).

**Triassic of the Afghan South Pamirs (Wakhan)**

Wakhan, in the extreme northeast of Afghanistan, forms part of the South Pamirs that may have originally belonged to the same geostuctural domain as the Central Mountains (Figure 1). Nevertheless, the facies of the Triassic succession are different to those of the Central Mountains. Lying concordantly upon Upper Permian fusulinid limestone, this succession consists essentially of terrigenous sandstone, siltstone, and siliceous slate containing rare dark limestone bands. Coal seams and plant impressions occur in the upper part. The beds are more than 2,000 m thick and generally unfossiliferous. They are assigned to the Triassic by analogy with the more fossiliferous series in the southern Pamirs. Following these comparisons, it would appear that the greater part of the sequence should be assigned to the Upper Triassic (Norian, Rhaetian). The sequence is overlain transgressively and with slight discordance by lowermost Jurassic marine beds (Abdullah et al., 1977).
Nouristan
The sedimentary rocks of Nouristan are poorly known. According to Sborshchikov et al. (1973) and Abdullah et al. (1977), within these high mountains there is a thick Triassic terrigenous sequence (>1,500 m) in a facies analogous to that of Wakhan, and equally unfossiliferous and slightly metamorphosed. Lower Cretaceous and younger plutons intrude the sequence.

Triassic of Southeastern Afghanistan

Triassic of the Kabul Block
Triassic rocks form part of the Permian-Cretaceous carbonate Khinguil Series that are discordant upon the Kabul Block Proterozoic basement. It concordantly overlies the Upper Permian (Djulfian) Productus limestones, although Ishii et al. (1971) reported a brief sedimentary lacuna. The Triassic is thinner (about 500 m) than in the Central Mountains and is distinguished from the latter by the following characteristics:

- Rocks of Early Triassic age, identified by Hayden (1911) consist of about 50 m of marly limestone containing cephalopods. They are characterized by a succession of Claraia- and Ophiceras-bearing faunas; for example, Proptychites, Gyronites, Eumorphotis, Prisnolobus, Flemingites, Meekoceras, Anakashmirites, and Danubites, in the Koh-e Safi region (Fischer, 1971; Ischii et al., 1971; Mennessier, 1977). According to these authors, the age of the cephalopod-bearing limestone may extend into the Anisian as indicated by the presence of Danubites.

- Most of the Middle to Upper Triassic (about 400 m) consists of dolomitic limestone and gray dolomite, with vermicular limestone at the base. These beds contain intra-formational breccias and beds of greenish volcanic tuffs (Fischer, 1971) that resemble the ‘pietra verde’ found in other Tethyan regions. They have yielded only indeterminable organic debris.

- The Triassic sequence is completed by Rhaetic limestone about 30 m thick containing Megalodon and Dicerocardium faunas, which are overlain conformably by a Jurassic limestone sequence (Fischer, 1971).

Triassic of the Allochthonous Series
The allochthonous Kotagae Series overlies the platform deposits of the Kabul Block, or forms a tectonic unit within the Rokian and Khost series and the Belouch Ranges. Allochthonous Altimour limestone massifs also occur along the edge of the Kabul Block, and the Belouch Ranges include a Triassic fauna. These tectonic uncertainties make paleogeographic reconstruction difficult (see Figure 28). From north to south and southwest, the allochthonous series are as follows:

- The Kotagae Series comprises at least 1,000 m of dark shale with intercalations of black, radiolarian limestone and dark-red radiolarites. Associated with these beds are mafic and ultramafic masses and calcareous olistoliths. Fauna is sparse, but the bivalves Halobiids or Daonella indicate a Triassic age. In the same series, Abdullah et al. (1977) described 1,000 to 3,000 m of shale and volcanics with calcareous partings and lenses (olistoliths?) containing Norian-age corals Thecosmilia cf. fenestrata (Ruess) and T. norica Frech. The upper part of the Kotagae Series may be as young as the early Senonian (Late Cretaceous).

- The allochthonous Altimour limestone massifs at the southeast margin of the Kabul massif tectonically overlie the Kotagae Series (Mennessier, 1977). No pre-Paleozoic basement is known and the Altimour limestone differs considerably from that of the Khimguil Series of the Kabul Block. The Triassic, concordant upon Djulfian (Late Permian) beds, begins with a red and white, ammonitic, nodular limestone of the ‘ammonitico rosso’ facies less than 10 m thick. A lacuna is present in the lowest Scythian. This condensed sequence has a rich Scythian fauna of Flemingites, Owenites, Anakashmirites, and Tirolites, and Anisian Danubites and Ginnites (Kummel, 1968; Kummel and Erben, 1968; Collignon, 1973). The overlying dark limestones with yellowish, argillaceous partings are 100 to 800 m thick and contain at their base the Ladinian ammonites,
Protrachyceras, Ptychites, Cladiscites, and Daonella indica Bittner. Rare Carnian ammonites occur (Collignon, 1973; Mennessier and Collignon, 1973). The uppermost, undated limestone beds pass without discontinuity into dated Jurassic rocks (Mennessier, 1977).

- The Rokian Series crops out south and southeast of the Altimour massifs in the Beloutch Ranges. The lithology is similar to the Kotagae Series; namely, thick dark shale with black radiolarian limestone, radiolarites, mafic volcanic intercalations, and calcareous olistoliths. In the exposed lower part, the discovery of Daonella moussoni (Merian) indicates a Middle Triassic age (Mennessier, 1977).

- The Khost calcareous flysch (Cassaigneau, 1979) has been thrust eastward over the Mesozoic Khost ophiolites to rest on the autochthonous foreland of Pakistan. The sequence consists of 2,500 m of calcareous microbreccias (turbidites) with radiolarite, siliceous shale, radiolarian limestone, and quartzite. The microbreccias contain abundant shallow-water microorganisms (primarily Upper Permian fusulinids), derived by gravity flows from a carbonate platform. Microorganisms such as Duostominids and Involutina that indicate a Triassic age are also displaced and may not be contemporaneous with the deposit. Thus, the presence of rocks of Triassic age in the lower part of the Khost flysch is tentative. The upper units (Tani and Khorrem Series) have been assigned a Jurassic to Early Cretaceous age (Kaever, 1969).

Triassic of Mar-Koh near Jalalabad

The Triassic succession of Mar-Koh (about 40 km southeast of Jalalabad and north of the Peshawar road) has been known since the time of Hayden (1911) and deserves a special mention. It differs strongly from the terrigenous deposits of Nouristan to the north and is separated from them structurally by a band of ultramafic rocks north of Mar-Koh that was considered by Stöcklin (1977) to be the continuation of the Mesozoic ophiolite belt of Baluchistan.

The Mar-Koh Triassic rocks therefore belong to the margin of the Indian Platform and not to the domain of the Central Mountains-Nouristan-South Pamirs. The thick (about 1,500 m) series discordantly overlies Upper Permian Waagenophyllum beds; the Early Triassic is apparently absent (Wolfart and Wittekindt, 1980) as the lowest marly limestone pseudobreccias (about 300 m thick) are of Anisian age. They contain the conodonts Daonella indica (Stoppel, in Wolfart and Wittekindt, 1980), ammonites (Gymnites), and brachiopods (Abdullah et al., 1977). Above 350 m of barren limestone there is an interval of dolomitic limestone 500 m thick, with quartzite intercalations, which have yielded Megalodonts (Megalodon sp., Dicerocardium? sp.) and Carnian to Norian conodonts. The sequence is completed by a 400-m-thick, coral-bearing, dolomitic limestone containing Thecosmilia clathrata Emm. Similar sequences are found in Pakistan near Peshawar, except that rocks of Early Triassic age are present. To the east on the Indian Platform, the beds become progressively more terrigenous and include Middle Triassic continental deposits (Ibrahim Shah, 1977).

JURASSIC STRATIGRAPHIC SUCCESSION

The Jurassic of Afghanistan was first recognized on the northern slopes of the Hindu Kush where the plant- and coal-bearing Saighan Series (Figure 9) forms a continuation of similar units in Iran. Since they were first identified by Griesbach (1885) and Hayden (1911), numerous studies have been conducted and reviewed by Mennessier (1961). However, the Jurassic stratigraphy is generally poorly known as fossiliferous beds are rare and dispersed, even though Jurassic rocks are fairly widespread (Kaever, 1967b).

Neocomian (end Jurassic–earliest Cretaceous) affected a large part of Afghanistan and created a major paleogeographic and stratigraphic break. This coincided not only with the Jurassic-Cretaceous boundary but is commonly recognized between the Neocomian (Berriasian–Hauterivian) and younger Cretaceous beds. Because of this, the Neocomian is considered with the Jurassic in this paper.
Jurassic of Northern Afghanistan

Saighan Series

This sequence is exposed at the type locality of Saighan (Figure 9) on the western slope of the Hindu Kush (Hayden, 1911), at Doab, Ichpuchta, and further north in Afghan Turkestan at Dara-e Suf, Karkar, and perhaps in the Band-e Turkestan (Figure 10b), according to Lapparent and Stöcklin (1972). The stratigraphic setting of the Saighan Series is well known (Lapparent and Lavigne, 1965). They were deposited following the Eocimmerian (latest Triassic–earliest Jurassic) folding that led to the closing of the North Hindu Kush Rift (Boulin and Bouyx, 1977). They rest with marked discordance on the Triassic, which includes Rhaetian (Figure 10a), and overstep the metamorphic basement.

In the type area, the rocks are entirely continental and generally lack volcanic rocks, in contrast to the underlying Triassic. From the base upward they consist of marls and variegated sandstones with minor conglomeratic intercalations, overlain by coal lenses or beds up to 1 m thick, alternating with sandstone and marls (coal measures of Dara-e Suf and Dohan-e Far; Mériaux, 1966). These two sequences yielded a rich flora, such as, *Cladophlebis*, *Coniopteris*, *Laccopteris*, *Equisetites*, *Nilssonia*, *Ginkgoites*, and *Podozamites*. A detailed list of the flora is given in Furon (1927) and Mennessier (1961), with spores and pollen identified by Wolfart and Wittekindt (1980). The upper sandy and marly sequence contains thick beds of gray conglomerate. The total thickness of coal measures at Ichpuchta may exceed 1,500 m.

The age of the Saighan has been variously interpreted (see Mennessier, 1961). The flora is clearly post-Rhaetian and the plants in the lowest beds are comparable to the uppermost Lower Jurassic of the Iranian Shenshak Formation. However, the plants associated with the coal at Ichpuchta, for example, are attributable to the Middle Jurassic according to Benda (1964). The flora is Angarian, which occurs in other areas of Central Asia (such as Ferghana), and extends into Western Europe.

In the eastern area near Karkar, northeast of Pul-e Khumri, the upper part of the sequence above the coal measures contains marine intercalations. This is the Karkar Formation of Desio et al. (1965). The lowest marine limestone directly overlies coal beds and contains an abundant fauna of Middle Jurassic solitary corals (*Montlivaltia*) and bivalves (Furon and Rosset, 1954; Rossi Ronchetti and Fantini Sestini, 1961). A more precise Bathonian age is indicated by foraminifera (Desio et al., 1965) and particularly...
by Zigzagceratid ammonites (probably *Waagnericeras aff. arbustigerum* d’Orb.; Lapparent and Lavigne, 1965), *Procerites* sp., *Distichoceras cf. bispinatum* Ziet. (in Wolfart and Wittekindt, 1980). Other marine units alternating with continental red clays and gypsum indicate a Callovian, Oxfordian, and even later Jurassic age based on a fragment of *Aulacosphinctes cf. infindibulum* Uhlig.

![Figure 10](http://pubs.geoscienceworld.org/geoarabia/article-pdf/14/1/147/5444251/montenat.pdf)

**Figure 10:** In northern Afghanistan, the Jurassic Saighan Series is commonly contained by unconformities below (a) and above (b).

(a) Major unconformity between dark-colored Triassic sandstones and light-colored Jurassic variegated marl, plant-bearing sandstone, coal, and conglomerate of the Ichpouchta (Saighan) Series;

(b) Light-colored Jurassic continental shale and plant-bearing sandstone of the Saighan Series unconformably overlain by dark-colored Upper Cretaceous (Senonian) marine deposits near Gudah, Band-e Turkestan.
The Saighan Series and its lateral equivalents thus cover the entire Jurassic. The lower part is related to the Early and part of the Middle Jurassic; the coal measures are Middle Jurassic in age (Lapparent and Lavigne, 1965); and the younger beds span the Bathonian to Late Jurassic.

The Jurassic Saighan Series is commonly overlain with angular discordance by Lower Cretaceous sandstones and red conglomerates known as the Red Grits (Griesbach, 1886).

**Other Jurassic Sequences of Northern Afghanistan**

Saighan Series-type deposits are not uniformly distributed across northern Afghanistan. Examples are as follows:

- Facies variations occur in the Karkar sequence.
- Up to 2,000 m of continental dark shale and sandstone with plant fragments and vertebrate footprints crop out in the core of the Band-e Bayan uplifted block to the southwest of Maymena (Figure 1). They were assigned to the Jurassic by Lapparent and Stöcklin (1972). Late Cretaceous marine deposits overlie the Jurassic with marked unconformity (Figure 10b) in Band-e Turkestan.
- In the Cheberghan region east of Mazar-e Sharif, the continental Triassic is overlain by 400 m of detrital limestone followed by lagoonal or marine dolomitic limestone attributed to the Oxfordian; plant beds and coal are absent.
- In Badakhshan, in the western frontal ranges south of Talukan, Bratas et al. (1970) described a terrigenous sequence at least 2,000 m thick that contained coal measures similar to the Saighan Series but with volcanics in the lower part. These beds are overlain by 200 m of lower Upper Jurassic limestone and dolomite.
- Bratas et al. (1970), consider that the Jurassic has a different character to the east-northeast of Talukan (Kulafghan), although only a few tens of kilometers distant. A reduced (185 m thick) terrigenous equivalent of the Saighan Series is attributable to the Middle Jurassic. The younger beds contain continental clastic rocks and volcanics, and some limestone of Late Jurassic age occurs in the upper part.

According to Lapparent and Lys (1972), Jurassic evaporites are associated with red marls near Khwahan. In Central Badakhshan east of Faydzabad, there are only fragmentary records of the Jurassic because of complicated tectonic events. The Upper Jurassic, fine-grained, black limestone is well bedded and occasionally bituminous, and contain molluscs such as *Ctenostreum proboscideum* (Sowerby), *Pholadomya canaliculata* Roem., and *Pinna* sp. (Desio et al., 1964).

**Jurassic of the Band-e Bayan Block and the Farah Rud Domain**

South of the Herat Fault, the Jurassic deposits of Band-e Bayan and Farah Rud are radically different from those in northern Afghanistan. They belong to a separate paleogeographic unit, of which Band-e Bayan represents the northern margin, and Farah Rud a deep basin.

**Jurassic of the Band-e Bayan Block**

The Jurassic deposits are discontinuous and complexly deformed. Marine Jurassic carbonates that occur near Jam are occasionally reefal and with sandy or marly intercalations. The bivalve, brachiopod, and ammonite fauna indicates a Toarcian to Oxfordian age (Abdullah et al., 1977). Southwest of Jam, shelly belemnite limestone occurs that are possibly of Late Jurassic age (Wittekindt, 1973). Similar deposits, mainly limestone with reefal intervals of Early to Middle Jurassic age occur in Band-e Bayan east of Jam and toward Panjaw (Abdullah et al., 1977). Shallow-water reefal deposits pass southward into deeper water facies toward the Farah Rud Basin. The Band-e Bayan area was emergent during the Neocomian (Berriasian–Hauterivian) and perhaps as early as the latest Jurassic.
Jurassic and Lowermost Cretaceous of the Farah Rud Basin (see Figures 6a, b)
The Farah Rud Basin contains 3,000 m of intensely folded, alternating gray-brown, pelitic and sandy Jurassic and Neocomian (Berriasian–Hauterivian) deposits representing flysch turbidite sedimentation. Rare carbonate intercalations with bioclasts and ooids are included in the gravity flow deposits of the Panjaw Flysch (Blaise et al., 1978). Immediately north of Panjaw, black reefal limestone with corals and sponges (Cladocoropsis) and carbonaceous lenses are intercalated in sandy pelitic deposits containing plant debris and fragmentary ammonites and belemnites. These deposits indicate the proximity of the northern margin of the basin, linking them with the Band-e Bayan Block.

The flysch becomes thicker and monotonous to the south and southwest toward the center of the basin; northeast of Dehkundi, they consist of turbidites with helminthoid traces (Figure 11). The receiving basin deepened from north to south. The southern marginal deposits are unknown, as the southern limit is entirely tectonic.

The Panjaw Flysch is separated from the Waras Ophiolitic Complex to the south and southeast by a system of major faults (Blaise et al., 1978); hence, stratigraphic relationships have not been established. According to Karapetov et al. (1975), Slavin (1974), and Abdullah et al. (1977), the two sequences are concordant. However, the Jurassic flysch shows a weak metamorphism (maximum sericitic grade), whereas the ophiolitic complex is more strongly metamorphosed (see preceding section) so that a phase of deformation between the two units cannot be excluded. The flysch was folded and slightly metamorphosed prior to the deposition of the red conglomeratic molasse and the overlying Barremian-Aptian marine orbitilinids beds (Figures 6b and 12) (Lapparent, 1962).
A Tithonian age is indicated by the occurrence of *Hemispiticeras steinmanni* Staar north of Panjaw (Mensink, 1967; see above). A general Late Jurassic age is suggested by the presence of *Cladocoropsis mirabilis* associated with biohermal masses south of Khar-Gol (about 50 km west-southwest of Panjaw) and by calcareous turbidites containing littoral fauna (*Lenticulina*, *Epistomina*, *Nodosaria*, *Serpula quadrata*, and ooids); their matrix contains pelagic elements, such as indeterminable ammonites, radiolaria, and the calpionellids *Tintinnopsella carpatica* Mur. and Fil., and *Remaniella cadishana* (Colom) of Berriasian or Valanginian age.

Still farther to the southwest near Pasaband, dark pelagic limestone intercalated in the flysch contain the calpionellids *Calpionella undelloides* Colom, *Calpionellites darderia* (Colom), *Calpionellopsis thalmanni* (Colom), and *Stenosemellopsis hispanica* (Colom), indicating Tithonian and Valanginian ages (Wittekindt, 1973). Slavin (1974) and Abdullah et al. (1977) suggested the presence of older Jurassic rocks but this has not been proved.

Finally, in the allochthon of Rushan Pshart, the volcano-sedimentary sequence adjacent to the Waras Ophiolitic Complex is overlain by a thick pelagic Jurassic-Lower Cretaceous succession and can be considered as the equivalent and eastern extension of the Panjaw Flysch.

### Jurassic of the Central Mountains

There are two Jurassic paleogeographic units in the Central Mountains delimited by the Helmand and Chaman Faults (see Figure 1). They are:

- The platform of the Central Mountains.
- The volcano-sedimentary basin of Kandahar on the southeast margin of the Central Mountains.

### Jurassic of the Central Mountains Platform

Montenat and Bassoullet (1983) studied the stratigraphy and paleontology of this region. The Jurassic paleogeographic evolution was more complex than during the Triassic. The type section is in the Oruzgan and Aw Paran regions but there are significant lateral variations to the southeast and northwest (Figure 13).

In the Aw Paran region, the Rhaetian Megalodont limestone passes up into about 100 m of gray, yellow, or reddish nodular or pseudobrecciated dolomitic limestone with marly partings. The micro- and macrofauna both indicate a Rhaetian age (Lapparent and Blaise, 1966). These limestones are overlain by terrigenous red or green marly sandstones with dark calcareous intercalations. The lowest, violet-colored calcareous intercalations have a similar facies to the Rhaetian, whereas the younger calcareous intercalations have a distinctly different microfacies with pellets and oolites resembling Lower Jurassic equivalents. The argillaceous marls, about 100 m thick that cap the sequence, contain Lower Jurassic molluscs.

Thus, the boundary between the Triassic and Jurassic lies within a terrigenous sequence. The lower members show continental influences following an end-Triassic regression. The upper members contain Lower Jurassic transgressive units (Figure 13). The angular discordance between the dark Jurassic limestones and the underlying terrigenous deposits indicate tectonic movements in the latest Triassic to earliest Jurassic.

The terrigenous series underlie about 300 m of dark limestone. At Aw Paran, about 150 m of Lower Jurassic rocks comprises the following units:

- Fine-grained, black, fetid, dolomitic limestone has a non-characteristic microfauna of *Parafavreina thoronetensis* Br. and Z. and *Ataxophragmiides*, suggesting a very early Jurassic age.
- Dark, oolitic limestones with ooliths and oncoids have a more abundant microfauna with *Pseudocyclammina* cf. *basica* Hoot, and *Involuitina* cf. *liasica* (Jones) indicating a Middle Pliensbachian age.
Friable dolomitic limestone with ammonites (*Uptonia* gr. *jamesoni* Sowerby; Lapparent et al., 1966) and foraminifera (*Involvulina* gr. *liassica* (Jones), are also Middle Pliensbachian in age (Carixian).

There is no evidence of deposits younger than Middle Pleisbachian (Carixian) at Aw Paran.

At Oruzgan, rocks of the Middle and Upper Jurassic series that follow without any apparent break from the Lower Jurassic are well developed. They consist of bioclastic and oolitic limestones that have the following age ranges (Figure 13) (Lapparent et al., 1966; Montenat and Bassoullet, 1983):

- Bajocian: Rhynchonellids and ammonites, *Leptosphinctes* (*Leptosp*.) sp., *Leptosphinctes* (*Cleistosphinctes*) sp. similar to *L. (C.) obsoletus* Pavia (Late Bajocian; Subfurcatus zone).
- Bathonian: foraminifera (*Nautiloculina oolitica* Mal.) and *Trocholina conica* Schlem. (Montenat and Bassoullet, 1983); belemnites (*Hibolites* sp.), and echinidoids (*Clypeus* sp.).
- Callovian: belemnites and *Macrocephalites* sp. It is a thin sequence with several hardgrounds.
- Early Kimmeridgian (probably Platynota zone): marly ammonite limestone with *Progeronia* sp., *Lithacoceras* cf. *subachilles* Weg.; thus, there is a stratigraphic gap with the Oxfordian absent.

About 400 m of black shale and black nodular radiolarian limestone continue the Kimmeridgian section. Lituolid foraminifera indicate a Late Jurassic age. Interbedded with the pelagic deposits are silty calcareous turbidites. They are succeeded conformably by 50 m of sandy limestone, sandy limestone with reworked ooliths (possible gravity flow deposits), limestone with abundant sponge spicules, and oolitic limestone. The numerous lituolids and trocholines foraminifera, such as *Trocholina* gr. *alpina* and large *Ophthalmedium*, suggest a latest Jurassic age. The rocks were deposited in shallow-water environments.

Considerable changes occur to the northwest and southeast of the Aw Paran-Oruzgan region (Figure 13).

**Northwest.** The Bum-e Robat section first described by Lapparent et al. (1969) has been redescribed and reinterpreted by Montenat and Bassoullet (1983). It consists of a sequence, at least 1,000 m thick, of Rhaetian to Callovian age. Widespread Megalodon limestone overlies the Rhaetian. Terrigenous

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**Figure 13: Mesozoic sequences of the Central Mountains.**
clastic deposits (marl and sandstone), about 600 m thick, underlie dated Callovian sedimentary rocks. Limestones of Early and Middle Jurassic age, well developed at Aw Paran and Oruzgan, here consist of thin carbonate intercalations within dominantly continental plant-bearing sandstones.

A Callovian sequence about 400 m thick consists of alternating sandy limestone, marl, and sandstone. Although the continental influx remains important, the open-marine influence is indicated by an ammonite fauna of Lower Callovian age; such as, *Hectococeras* sp., *Choffatia* (*Choffatia*) sp., *Indosynthia* aff. *brenoni* Col., *I. (I.) aff. urbanus* Spath, and *I. (Elamites)* sp. (Montenat and Bassoullet, 1983), and of Middle Callovian age: *Reineckeia* sp., *Kosmoceras* sp., and *Grossouvria* sp. (Lapparent et al., 1969). The Callovian also contains bivalves and simple corals (*Montlivaltia*, *Chomatoseris* sp.; Gill and Lafuste, 1971). No Late Jurassic deposits are known in the Bum-e Robat region.

The Kadjao Valley section, about 100 km to the northeast of Bum-e Robat, is quite different. Neocomian (Berriasian–Hauterivian) or uppermost Jurassic rests with angular discordance on Rhaetian Megalodon and Involutine limestone. It is probable that during most of the Jurassic the area was emergent, and a red argillite underlies an unconformity surface. The Aw Paran and Kadjao successions are separated by the Kadjao Fault that was active throughout the Paleozoic and Mesozoic (see Blaise et al., 1977, 1982; Bordet et al., 1976; and Vachard and Montenat, 1981). The fault separated an uplifted northern and northwestern area, such as Kadjao, from the area to the south and southeast where the sections are always more complete, as for example Bum-e Robat.

**Southeast.** The Lower Jurassic at Mokur consists of 400 m of marine carbonates that overlie dolomitic Rhaetian limestone. The sequence consists of about 180 m of undated black, bedded to massive limestone with brown calcareous shale and black nodular limestone, followed by about 200 m of massive black coral limestone containing molluscs and foraminifera (*Orbitopsella* cf. *praecursor*) assigned to the middle Lower Jurassic by Lapparent et al. (1970) (Figure 14). Re-examination of this succession by Montenat and Bassoullet (1983) did not confirm the presence of *Orbitopsella*, but the microfauna probably contains the lowermost Jurassic forms *Involutina farinacci* Br. and Z., ‘*Ophthalmidium*’ *mortanum* Fab., *Cyclogyra* sp., and *Pseudocyclammina* aff. *iassica* Hott. The black limestone is capped by about 50 m of sandstone and shelly limestone of middle Early Jurassic age (Lapparent et al., 1970) and by 350 m of thick-bedded, black, undated limestone. The succession is unconformably overlain by Lower Cretaceous clastic rocks (Figure 14).

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**Figure 14:** Disharmonically folded Lower Jurassic limestones unconformably overlain by massive Cretaceous conglomerates, Mokur area.
A similar section is found near Gohar northwest of Mokur on the left bank of the Arghandab River (Lapparent, written communication, 1972). In both sections the Upper Triassic-lowermost Jurassic continental terrigenous deposits are present at Aw Paran and Oruzgan.

At Misan on the southeastern border of the Central Mountains northwest of Qalat, Paulsen (1971) described a similar Jurassic sequence. Here, the Sarak Anticline exposes a core of Rhaetian limestone that is overlain by a detrital and bioclastic sequence on its northwestern flank (compare with Aw Paran). On its southeastern flank, terrigenous deposits, sandstones and shales thin out in favor of bioclastic limestone. The lateral facies change that occurs across the Sarak anticline is oriented northeast parallel to the southeastern margin of the Central Mountains. It corresponds to the development of marine deposits, as at Mokur, from the interior of the Central Mountain Block toward its southeastern margin. In the Misan region, the carbonates, tentatively assigned to the Middle and Upper Jurassic, thicken in the same direction.

In summary (see Figure 13):

- **During the Early and Middle Jurassic**, the Central Mountains platform continued in existence from the Triassic, but differed by dipping eastward so that its western part was emergent and undergoing erosion while the subsiding eastern margin passed into an open-marine environment.

- **During the Late Jurassic**, important physiographic changes occurred. In the Oruzgan section, an Oxfordian lacuna was probably a break in sedimentation rather than a period of emergence, and there was the start of pelagic sedimentation with shale containing calcareous nodules. Along the southeastern border of the platform, conditions were different as oolitic Middle Jurassic limestone at Surkhbed and Abatu Chellah (between Tirin and Kandahar) are overlain by bauxite horizons several meters thick followed by lacustrine or brackish deposits (Figure 15) Lapparent, 1969; Girowal et al., 1979). This emergent (bauxitic) interval may equate with the non-depositional interval (Oxfordian) recorded at Oruzgan.

- **During the latest Jurassic**, sedimentation was quite different. At Surkhbed and Abatu Chellah, pelagic deposits are replaced by neritic limestone with biothermal rudists, corals, nerinids, algae, foraminifera (such as, *Pseudocyclammina lituus* Yok., and *Trocholina alpina* Lep.), and sponges (*Cladocoropsis mirabilis* Felix) (Paulsen, 1971; Montenat and Bassoullet, 1983). The same fauna is also present in the Misan region where the Upper Jurassic consists entirely of detrital platform carbonates (Paulsen, 1971). This generalization appears valid for the whole southeastern margin of the Central Mountains that, during the latest Jurassic, formed a ridge marked by emergence or neritic sedimentation. The ridge separated the Oruzgan Trough with its black shales, to the northwest, from the pelagic Kandahar Basin to the southeast (Karapetov et al., 1975). The Kandahar volcano-sedimentary basin (see below), is related to the Surkhbed section where rhyolitic tuffs overlie the bauxite horizons (Figure 15).

**Marginal Volcano-sedimentary Kandahar Basin**

The Kandahar volcano-sedimentary basin is located on the southeastern margin of the Central Mountains. To the east, the basin is truncated by the Chaman Fault that marks the boundary with the Beloutch Ranges (Figure 16a). The basin is closed toward the northeast in the vicinity of Qalat but opens southwestward before disappearing below the dunes of the Seistan Desert. The same beds reappear farther south in Pakistani Baluchistan. The characteristics of the basin can be summarized by a traverse from north of Kandahar to Spin Boldak (Bordet et al., 1979; Montenat et al., 1979, 1983, 1986; Ouedraogo, 1985) (Figures 16a, b). There are two principal lithologic assemblages:

1. Volcanics and volcanioclastics that are more than 1,000 m thick. They are not part of an ophiolite suite as was suggested by Karapetov et al. (1975), but consist mainly of a diverse calc-alkali suite. On the northern margin, about 40 km north of Kandahar, are explosion breccias, ash deposits, lava domes, and subaerial dacite and calc-alkali rhyolite flows. Intercalated within the volcanic deposits is a neritic limestone with molluscs (*Nerinea*, and oysters), foraminifera (*Pseudocyclammina lituus* and *Anchispirocyclina praehusitanica* (May), and algae (*Pseudoactinoporella* and *Carpatoporella*) indicative of a Late Jurassic (Kimmeridgian) age.
(2) Farther to the south, about 25 km north of Kandahar, the volcanics have a different character. They are at least 1,000 m thick and consist of pillow lavas and dark, mafic hyaloclastites alternating with black shale and radiolarites (Figure 17). These volcanics were clearly erupted in a deep-marine environment. Dolomitised carbonate olistoliths are enclosed within the volcanioclastics. The radiolarites commonly show evidence of slumping. They also display thin oblique stratification, related to deep-water contour currents (contourites). At Keshenakhud, west of Kandahar (Figure 16a), the volcanics directly overlie the Proterozoic basement (Behsud Series) of the Central Mountains that is intruded by feeder dikes to the volcanics.

Still farther to the southeast, 25 km northwest of Spin Boldak, volcanics of the northeast-trending Adi Ghar Range are subaerial (as on the northern margin of the basin). The upper part of the volcanic sequence contains blocks and slumped lenticular masses of orbitolinid limestone of Bedoulian age. The latest eruptions were Early Aptian.

(3) Overlying the volcanics are carbonates that mark the closing of the volcanic episode. They are diachronous being older (Late Jurassic) in the northwest, passing to Aptian in the southeast. To preserve the stratigraphic unity, the Jurassic and Cretaceous rocks are here treated together.

The effects of bathymetric variation from the margin north of Kandahar toward the center of the basin (the Adi Ghar island arc) (Figure 16a) must be added to the diachronism of the volcanics and overlying limestone. The post-volcanic sediments indicate a deepening southeastward toward the center of the basin. North of Kandahar, shale and fine-grained limestone were deposited in very shallow water, with *Cladocoropsis, Pseudoclammina lituus* Yak. and miliolids indicating a Late Jurassic or earliest Cretaceous age. These sediments have been transported by gravity downslope into deeper parts of the basin.

In contrast, south of Kandahar at Kotal Ghundey the volcanics are overlain by pelagic limestones (Figures 16b and 18). The limestones incorporate reddish ferruginous beds containing ammonites, commonly *Phylloceras* (*Holoclyophylloceras* *calypso* d'Orb.) and *Lytoceras*, together with *Protetragonites* sp., *Neocomites* sp., *Berriasella* (B. ex gr. *moreti* Maz.), *Spticeras* sp., S. ex gr. *chaignoni* Sayn, and probably *Himalayites* and *Polyptychites*; a Late Tithonian or Berriasian age is indicated according to Montenat et al. (1979). An overlying sequence of calpionellid limestone contains *Calpionellites* ex gr. *darderi* (Colom), *Tintinnopsis* ex gr. *carpathica* (Colom), and *Stenosemellopsis* cf. *hispanica* (Colom) of Valanginian age.

Farther southeast, the lowest post-volcanic carbonates crop out in the valley of the Arghestan River. They are platy, reddish, gray, or yellow micritic limestones rich in radiolaria and interbedded with turbiditic, calcareous microbreccias. The sequence is of Early Cretaceous age.
Figure 16: The volcano-sedimentary Kandahar Basin (after Montenat et al., 1986).
(a) Geologic sketch map;
(b) Schematic cross-section of the basin (length of cross-section about 100 km).
Figure 17: Upper Jurassic pillow lavas and hyaloclastics in a deep-marine environment north of Kandahar. (Hammer for scale, 35 cm long).

Figure 18: Pelagic limestones containing calpionellids and ammonites, interbedded with volcanics (Upper Tithonian to Valanginian) at Kotal Ghundey south of Kandahar. (Hammer for scale, 35 cm long).
Thick neritic limestones with Aptian (upper Bedoulian and Gargasian) orbitolinids and rudists overlie the volcanics in the Adi Ghar Cordillera (see Figure 27). South of Adi Ghar, the post-volcanic Aptian limestones are pelagic and contain radiolaria and sponge spicules (Montenat et al., 1983).

The Chaman Fault forms the southeastern boundary of the volcano-sedimentary series of the Kandahar Basin and separates them from the Paleogene flysch of the Beloutch Ranges. The paleogeographic and geodynamic interpretation of the Kandahar Basin is considered in a later section.

**Jurassic of Wakhan**

The Wakhan region is the Afghan segment of the South Pamirs. It belongs paleogeographically and structurally to the same domain as the Central Mountains. The Jurassic succession consists of two units, one predominantly terrigenous and the other predominantly calcareous. The terrigenous succession, about 130 m thick, discordantly overlies Rhaetian-age rocks (Abdullah et al., 1977). An initially variegated continental sequence passes into marine deposits with calcareous intercalations that contain earliest Jurassic bivalves. The predominantly Lower and Middle Jurassic calcareous series is at least 250 m thick. The ammonite fauna indicates Late Toarcian (*Hammatoceras* sp., *Pachmatoceras* sp.; Isigne zone) and Bajocian (*Oppelia* sp., *Stephanoceras* sp., *Strenoceras bajocense* Deb., and *Parkinsonia* sp.) ages. No deposits of Late Jurassic age have been recorded. Russian geologists described a similar succession in the southeast Pamirs. Note that lithologic parallels can be drawn with the Aw Paran and Oruzgan sequences in the Central Mountains (see Figure 13).

**Jurassic of Southeast Afghanistan: Kabul Block and the Beloutch Ranges**

The sequence of Mesozoic structural units was outlined in the discussion of the Triassic. The same format is followed for the Jurassic.

**Kabul Block: the Khinguil Series**

The Khinguil Series has an age range of Permian to Cretaceous. There is sedimentary continuity between the Rhaetic Megalodon limestones and those of the lowermost Jurassic. There is no discordance and no terrigenous beds at the Triassic-Jurassic boundary. According to Fischer (1971), the Jurassic of Koh-e Safi, east of Kabul, consists of two main members. The lower Nerinea limestones are about 400 m thick and contain gastropods (*Procerithium*), solitary corals (*Montlivaltia*), and dasycladacean algae assigned to the Lower and Middle Jurassic. They are overlain by at least 150 m of belemnitic limestone identified as Callovian and Oxfordian by the presence of *Belemnopsis* and *Cylindroteuthis*.

These limestones indicate a marked deepening from the earlier shallow-water carbonates, with initial nodular limestone dating from the Middle and Late Jurassic. According to Mennessier (1977), the carbonates of the Khinguil Series are continuous into the Late Cretaceous.

**Jurassic of the Allochthonous Series**

The constituent units of the Allochthonous Series are described from southeast (Khost) to northwest (Kabul) (see Figures 5 and 29).

**Khost Series.** According to Cassaigneau (1979), this includes the Tani and Khorram formations of Keaver (1967a) and Bruggey (1973), and the Lohazur Formation. The Series consists of calcareous flysch deposits more than 2,500 m thick associated with radiolarites, radiolaritic limestones, and quartzite lenses. Its age is difficult to define as the microorganisms that occur have been displaced within calcareous turbidites. Some are clearly reworked from older (Late Permian) carbonates, whereas others are probably penecontemporaneous with the flysch. Cassaigneau (1979) considered that the Khost Series includes rocks of Triassic age in the lower part and extends into the Middle to Upper Jurassic.

- **Tani and Khorram formations.** Keaver (1967a) and Bruggey (1973) assigned the lower part of the Series (Tani shales and calcareous sandstones) to the Jurassic (Lower to Middle?) and the upper members (Khorram limestones and shales) to the Jurassic-Lower Cretaceous, based on the microorganisms (*Clypeina, Trocholina, Paratrocholina*) included in the calcareous microbreccias.
Mesozoic of Afghanistan

Lohazur Formation. (2,220 m thick; Kaever, 1967a) crops out near Alikhel, north of Khost. It consists mostly of a terrigenous flyschoid or graywacke facies containing plant debris and thin carbonaceous beds that are not necessarily continental but may represent a deep-sea fan. The Lohazur Formation is probably the lateral equivalent of the Tani Formation (see discussion in Wolfart and Wittekindt, 1980).

Rokian Formation. The Rokian Formation, about 1,500 m thick, crops out south of the Altimour Massif (see Figure 1) as shales, black radiolarian limestones, radiolarites, and olistolith limestones. The sequence also contains basalts and ultramafic bodies, notably up to 300 m of pillow lava, and tuffites in the lower part. According to Kaever (1967a) and Bruggey (1973), the Rokian overlies the Lohazur Formation and is Late Jurassic to Early Cretaceous in age, based on rare microorganisms (algae, Trocholinids, and Paratrocholinids) and mollusc remains. The fossils have been transported by gravity flows into a pelagic environment and so their biostratigraphic assignments are uncertain (compare with the Khorram Formation that is probably a lateral equivalent of the Rokian Formation; Wolfart and Wittekindt, 1980). However, according to Mennessier (1977), the lower part of the Rokian Formation contains fossils of Triassic age and makes a continuous transition to the Upper Cretaceous. If this is correct, the superposition of the Rokian Formation on the Lohazur Formation (equivalent to the Tani Formation) must be a tectonic contact. However, this ambiguity cannot be resolved because of the inadequacy of stratigraphic and structural data.

Altimour Massif. In the Altimour Massif there is continuous carbonate sedimentation from the Triassic into the Jurassic. The black Watch-Sakh limestones, variable in thickness up to 800 m, and with yellowish shale partings, contains a Triassic (Ladinian-Carnian) sequence in the lower part and molluscs (Lopha? or Ctenostreon), brachiopod remains, and Cidarids with Jurassic affinities in the upper part. According to the present author, calcareous sedimentation continued without a break into the Cretaceous (Sangae Limestones with corals and indeterminate bivalves). Some olistoliths in the upper part of the Rokian Formation were derived from the Sangae limestones (Mennessier, 1977).

Kotagae Series. The Kotagae Series is thrust over the autochthon of the Kabul Block (= Khinguil Series). It has a facies development similar to that of the Rokian Series, including turbiditic beds and should have the same stratigraphic limits of Triassic (?) to Upper Cretaceous. The presence of Jurassic rocks, however, has not yet been demonstrated except in the form of olistoliths. West of Sarobi, calcareous blocks within radiolarian shale contain neritic material, algae, faecal pellets, oncolites, Ataxophragmids, brachiopod debris (Spiriferina), and molluscs (Nerinea) similar to the facies present in the Lower and Middle Jurassic of the Central Mountains (Khinguil Series). These allochthonous blocks indicate a lower age limit on the enclosing rocks, but cannot date them. The Kotagae Series is overlain by the tectonically emplaced Logar peridotite nappe.

CRETACEOUS STRATIGRAPHIC SUCESSION

Cretaceous of Northern Afghanistan

Cretaceous deposits are unequally represented in three groups separated from one another by discontinuities, more-or-less well defined according to location.

‘Red Grits’

The earliest Cretaceous rocks were deposited during a continental interlude. This ‘Red Grits’ sequence consists of bright-red sandstone, marl, and conglomerate described by Griesbach (1886); the uppermost member is commonly a shaly red gypsum. The thickness of the Red Grits can vary from zero to 1,000 m (Abdullah et al., 1977). It is well developed on the northern and northwestern slopes of the Hindu Kush (Doab, Ichpouchta, Sar-e Poul), but thins to a more argillaceous phase toward the northwest of Mazar-e Sharif and in the Tachkourghan areas (Mennessier, 1962; Weippert, 1968).

At its base, the Red Grits rest with a more-or-less marked discordance on continental Upper Jurassic rocks of the Saighan Series or Karkar Formation (Mennessier, 1962; Lapparent and Lavigne, 1964, 1965; Desio et al., 1965), and locally on older beds. It is unconformably overlain by marine deposits of
varying age consisting of Senonian (mid to Upper Cretaceous) platform limestones that are widespread throughout northern Afghanistan. The lower part of these limestones contains sandy glauconitic limestone and marl of Late Aptian or Albanian age (Mennessier, 1961; Abdullah et al., 1977).

Although the Red Grits have not yielded characteristic fossils, it can be dated by its stratigraphic position. It partly or totally occupies the post-Late Jurassic and pre-Late Aptian-Albian interval. It may also be correlated with a similar sequence in Tadjikistan (Ovechkin, 1959; Mennessier, 1962). North of the Amou Darya River, there is a red-bed succession, without conglomerates but including marine intervals. This is the Almourad Series, with Valanginian fauna, the continental Hauterivian Kzyyltrach Series, and the Barremian-Lower Aptian Okouzboulak Series containing a Lower Barremian marine fauna. The Okouzboulak Series shows a marked similarity to the gypsiferous, argillaceous beds at the top of the Afghan Red Grits. According to Bratas et al. (1970), subsurface data indicate the presence of salt layers associated with the Red Grits of northern Afghanistan in the southern prolongation of the Tadjik Basin.

Neocomian (Berriasian–Hauterivian) marine molluscan fauna recorded from the Red Grits by Mennessier (1962) contains *Alectryonia rectangularis*, *Litschkovitrigonia tenuituberculata*, *Myophorella loewinsoni lessingi*, *Iotrigonia jakschisaurensis*, and *I. scapha*. The location of the samples is uncertain, but they may have been derived from near Mazar-e Sharif, where the Red Grits were intersected in a borehole (Weippert, 1968). If the provenance can be confirmed, it would suggest that these marine incursions extended into northern Afghan Turkestan, which is consistent with the general paleogeographic evolution of the Red Grits facies.

‘Green Beds’

This second sedimentary unit, defined by Popol and Tromp (1954), consists of various marine deposits. The basic sequence is an alternation of gray or greenish marls and bands of limestone or sandy limestone as much as 1,000 m thick, frequently containing glauconite and much molluscan debris (Figure 19). The gypsum and sandy beds are particularly common at the base and top of the Green Beds. The presence of sulphur and oil has been documented at several localities, such as Mazar-e Sharif and Sar-e Poul (Mennessier, 1961).

The Green Beds are either conformable, or unconformable as at Karkar (Desio et al., 1965), on the Red Grits. Where the latter is absent, the Green Beds are unconformable on older rocks (Abdullah et al., 1977).

The biostratigraphic data for the Green Beds are fragmentary and the location of fossils not precise, but there is general agreement to assign an age range of Late Aptian (?)–Albian to Early Senonian (mid-Late Cretaceous) (see the faunal lists in Mennessier, 1962). However, it must be noted that the lower part of the Green Beds may be more-or-less complete according to the location (see below). It is therefore impossible to give an overall view. The Albian is recognized by the presence of *Hypacantholithes* (H. ex gr. jacobi), *Dowvilleiceras mammillatum*, *Cleoniceras mangyschakensis*, *Hoplitites* ex gr. *dentatus*, and *Leymeriella tardifurcatus* (Mennessier, 1962; Abdullah et al., 1977; and Kolchanov, 1969). The Cenomanian at Pul-e Khumri has yielded the prealveolines *Orbitolina lenticularis*, and *Neoemeris* sp., and in the same location, the Turonian can be recognized by the occurrence of *Hippurites* sp., ammonites (*Mammmites*? and *Metaiococeras*?), and inoceramids such as *Inceramus pictus*, *I. labiatus mytiloides*, and *I. hercynicus* (Cita and Ruscelli, 1959; Weippert, 1968; Sornay, 1974).

The variations in facies and thickness of the Green Beds help to define the paleogeography of the Green Beds basin (Weippert, 1968), as follows:

- The depocenter lay in the north in the Mazar-e Sharif and Cheberghan regions where deposits are thickest and there is the best development of marl facies.

- Toward the east and south, approaching the Hindu Kush and Badakhshan mountain ranges, the succession progressively thins, and carbonates and clastic detritals become more dominant as at Pul-e Khumri in the Doab region. The transgression becomes progressively younger in this direction. At the above locations, the Albian is represented by undated, thin, basal detrital beds. At Saighan, rocks of Senonian age (Coniacian–Maastrichtian) transgress onto continental Jurassic.
Mesozoic of Afghanistan

Farther south again, the Campanian rests upon basement of the Hindu Kush (Lapparent and Lavigne, 1965) and this marks the southern limit of the Green Beds basin.

The basin can be traced to the west and northwest toward the Turkmenistan border. This western margin of the basin, sketched in by Weippert (1968), was confirmed by the presence of Senonian-age rocks discordantly overlying continental beds assigned to the Jurassic (Lapparent and Stöcklin, 1972) (see Figure 10b).

The basin extends north into Tadjikistan where equivalents of the Green Beds were deposited as the Kaligret and Alouat series (Ovechkin, 1959).

Upper Cretaceous Limestones

A third unit, the Exogyra (oyster)-bearing limestone of Griesbach (1886), or the ‘massive limestone series’ of Popol and Tromp (1954) and Mennessier (1962), is difficult to define. It consists of diachronous marl and sandy or marly limestone; massive limestone occurs in the upper part. The lower part may be of Santonian-Campanian age. Elsewhere, rocks of Maastrichtian age are always present, as are Paleocene beds in some area. The Exogyra-bearing limestone is markedly transgressive and overlies and oversteps regressive Upper Turonian-Coniacian detrital deposits that include variegated gypsiferous marls. Near Saighan and along the western limit in the Hindu Kush, the transgression is Campanian in age (Lapparent and Lavigne, 1964; Kolchanov et al., 1970b; Bouyx and Lang, 1982; Bouyx and Vilain, 1986; and Yabe, 1959). Thin Campanian limestones (<100 m thick) directly overlie the Jurassic Saighan Series or metamorphics of the Hindu Kush and are overlain by yellow marls (Figures 19 and 20) containing Micraster laxoporus, Hemiaster noemae, Neithia stratiocostata, Inoceramus balticus, Scaphites ex gr. hippocrepis. In turn, these are overlain by a reddish limestone with radiolarites, containing the oyster Lopha cf. diluviana, and Poropygus vaslini, and P. morgani. A thicker (about 200 m) Maastrichtian section consists of alternating marly and oyster-bearing limestones and contains other molluscs, such as Baculites sp., Actinophrya spectabilis, Hemiaster opinus, and Cyclolites regularis, and an associated microfauna Siderolites calcetrpoides and Orbitoides sp. (Lapparent, 1963).
The overlying massive cliff-forming dolomitic limestone also contains a Maastrichtian fauna, notably with *Cardita beaumonti*. Campanian and Maastrichtian rocks have also been identified in the Hadjar Valley, northwest of the above locations. The transgression there may have been earlier, in the Santonian (Kaever, 1963, 1968).

The Upper Cretaceous is well developed at the Band-e Amir lakes southwest of Saighan (Figure 21). There are two dominant lithologies. The first is a predominantly marly sequence about 350 m thick with limestone or sandy intercalations. It has a definite Campanian fauna of *Hoplitoplacenticeras, Echinocorys, Inoceramus, Pycnodontes*, and *Micraster* (Lapparent and Lavigne, 1965), but the lower part may be Santonian as defined by microfauna and inoceramids (Jux et al., 1971). The marly sequence is overlain by 400 m of cliff-forming Maastrichtian limestones containing, for example, *Orbitoides, Pycnodonta vesicularis, Exogyra conica, E. pyrenaica, Lima gallieni* and siliceous sponges.

The marine uppermost Cretaceous, consisting mainly of Maastrichtian units, occurs extensively in northern and northwestern Afghanistan. Northeast of Herat near Qala Naw (Kolchanov, 1969) and in Band-e Turkistan, the Late Cretaceous transgression did not cross a ridge of Jurassic rocks, probably uplifted in the Santonian (Lapparent and Stöcklin, 1972). At Ghalmine in the valley of the Murghab River (Figure 22), Lapparent (1974) recorded an interesting microfauna with *Navarella joaquini* in glauconitic limestones, probably Maastrichtian because of the occurrence of *Globotruncanca cf. stuarti*. In northern Afghanistan, these and Paleocene limestones have been quarried since ancient times and were used, for example, in building Ai Khanoum, one of the principal cities of the Greco-Bactrian Kingdom founded in the 4th century BCE (Lapparent and Desparmet, 1970). Elsewhere in the same region, Campanian and Maastrichtian rocks have yielded a rich rudist fauna (see listing in Vogel, 1971).
Figure 21: One of the famous ‘hanging lakes’ of Band-e Amir (the lake is about 15 m above the valley bottom and is held back by a tufa ‘dam’. The lake is surrounded by Campanian marl and Maastrichtian limestones.

Band-e Bayan and the Farah Rud Basin

It is convenient to treat these units together as both belong to the same paleogeographic domain with Band-e Bayan representing the northern edge of the Farah Rud Basin.

Neocomian (Berriasian–Hauterivian)
The Neocomian deposits of the Farah Rud Basin are intimately linked with those of the Upper Jurassic. They form part of a single, thick flysch deposit for which a Neocomian age is indicated by the presence of calpionellids (see section on the Jurassic), and younger units by ammonites (Neocomites aff. montanus Uhl.) of Late Valanginian–Early Hauterivian age (Abdullah et al., 1977). This pelagic sedimentation ended during the Neocomian when the basin was strongly compressed (see Figure 12), and an axial plane schistosity imposed during low-grade metamorphism (Blaise et al., 1978). Units of this age are not known in Band-e Bayan.

From Barremian–Bedoulian (=Lower Aptian) to the beginning of the Late Cretaceous
Following the closure of the Farah Rud oceanic basin, marine conditions returned after a phase of erosion that produced thick conglomerates. A shallow sea (known as the Orbitoline Sea) formed in which orbitolinids (larger foraminifera), rudists and corals are widespread.

- In the central, wider part of the basin (the Taywara-Pasaband area), active subsidence occurred. The orbitolinid Cretaceous sequence is several thousand meters thick (Wittekindt, 1973; Slavin, 1974; and Abdullah et al., 1977). Calcareous deposits are well developed, although there is a significant terrigenous content. Conglomerates, sandstones, and red marls are particularly well developed in the lower part of the sequence and also alternate with the limestones. The latter occasionally have a reddish tint due to outwash from a nearby continental area. Thick andesitic tuffs breccias have been reported.

The earliest dated marine units are Barremian (Abdullah et al., 1977). Near Taywara, Schroeder and Lapparent (1967) reported a primitive orbitoline fauna of Praeorbitolina cornyi (Schroe.; primitive form), Rectoidcycyonus giganteus, Dictyoconus aff. pachy marginalis (primitive form), ‘Orbitolina’ conconicoformis Mam. and Balkhania balkhania Mam., forms that indicate a probable Barremian age.
Orbitolinids occur in numerous locations (see listing in Wittekindt, 1973; Wittkindt and Weippert, 1973; Montenat et al., 1983). Two facts emerge from the identified microfauna. The oldest faunal associations Barremian-Aptian (or more probably Barremian) as at Taywara have been identified in small numbers in the western part of the basin in the Farah-Anardara and Taywara-Pasaband areas. Younger associations show that the Orbitoline Sea remained in existence during the Aptian and Albian, and even into the Cenomanian. A similar stratigraphic range of Barremian to Cenomanian was proposed by de Cizancourt et al. (1937) following work near Anardara in the westernmost part of the basin.

• In the eastern, narrowest, part of the basin, the Cretaceous sequence forms narrow compressed structures rather than the wide folds that are present to the west. They are commonly separated from the Jurassic flysch by major faults trending northeast or east-northeast. The principal exposures are in the Dehkundi-Panjaw region.

In spite of tectonic complications, significant differences can be recognized between the Neocomian and later deposits. The thickness of the younger deposits is much reduced, not exceeding a few hundred meters, a phenomenon that cannot be attributed to systematic tectonic thinning, and calcareous deposits form a more modest proportion of the sequence in comparison with the detrital content.

In this eastern part of the basin, the transgression of the Orbitoline Sea appears to have been later as no Barremian-Bedoulian orbitoline association has been recorded. In the Surkhqoli Valley west of Panjaw (for example, at Kurdak Takta; Lapparent, 1962; Schroder and Lapparent, 1967), detrital red beds rest discordantly upon epimetamorphic Jurassic flysch and are overlain conformably by about 100 m of calcareous sandstone containing Late Aptian orbitolinids.

South of Khargal (40 km from Panjaw), the first orbitolinid horizons above the red conglomerates are Gargasian (Middle Aptian) in age, with Orbitolina (Mesorbitolina) gr. texana Roem. and O. (M.) libanica Henson. They are followed by recurring continental deposits and gray reef limestone containing
corals, orbitolinids, and the radiolites *Eoradiolites cf. gilgitensis* (Douv.) and *Agripopleura* sp. Near Panjaw, Gargasian orbitolinids are evidence of brief marine incursions (Montenat et al., 1983).

To the north of Panjaw on the old track to Bamyan, there are extensive outcrops of red Cretaceous pelites, sandstones, and conglomerates containing re-worked epimetamorphic Jurassic flysch, deposited on the northern shore of the Orbitoline Sea. Tuffs and volcanic breccias are associated with the red beds (for example to the south of Panjaw, near Waras; see Figures 6a,b and 23).

There is evidence of marine incursions east of Panjaw within the red beds, where sandy limestone contains bivalves and *Perminoculis inopinatus* Ell. (Lapparent, 1962; Wittekindt, 1973), and also east of Kotal-e Molah Yaqub in the Turman Valley, where sandy limestone and yellow, lagoonal-marine dolomite occur. No orbitolinids have been found. These marine deposits represent the last transient incursions of the Orbitoline Sea. The Band-e Bayan Domain, where the Cretaceous outcrops are widely dispersed, lay on the northern shore of the Orbitoline Sea but a significant part must have remained emergent to separate the Farah Rud Basin from the Green Beds basin of Afghan Turkestan, as orbitolinids appear to be absent from that area.

**Upper Cretaceous**

The Cenomanian has only been recognized in the westernmost part of the Farah Rud Basin and the eastern part was probably emergent due to paleogeographic changes that occurred in the Late Cretaceous. Scattered limestones, often sub-tabular, discordantly overlie Jurassic rocks near Panjaw (Figure 6a,b). North of this locality are outcrops of massive, gray or reddish, marly limestone with molluscan debris. These limestones have yielded *Pithonella ovalis* Kauf. and bicarinate *Globotruncanasa*, indicating a Turonian or Coniacian to Santonian age (Cita and Ruscelli, 1959). At Panjaw meteorological station, the limestones consist of two distinct facies: gray limestone with indeterminate rudists; and fine-grained, gray, dolomitic, flinty limestone. The micro-fauna in the second facies includes *Globotruncanac* *lapparenti* Brot., numerous *Pithonella* (*Pithonella ovalis* Kauf., *P. innominata*, and *P. sphaerica*), and sponge spicules (determined by J.M.Villain). This association indicates a probable Campanian age. Twelve kilometers west of Panjaw (and north of the central track), more marly and deformed beds show a similar microfacies of *Globotruncanac* and *Pithonella ovalis* and *P. innominata*, and sponge spicules and *Inoceramus* prisms, again probably Campanian in age.

![Figure 23: The Lower Cretaceous Red Grits in the Waras area. They include andesitic volcanics and reworked debris of the Waras Ophiolitic Complex. Thin intercalations of marine mid-Cretaceous limestones are present in the upper part. Units of the Waras Ophiolite Complex are thrust over the Red Grits in the background to the right.](http://pubs.geoscienceworld.org/geoarabia/article-pdf/14/1/147/5444251/montenat.pdf)
Farther east in the Turkman Valley, cliffs at Parandaz are also formed of sub-tabular Upper Cretaceous limestone resting discordantly on a shaly Triassic sequence, and possibly on Jurassic rocks (Lapparent et al., 1974) (Figure 24). Elsewhere, these limestones are totally independent of the Lower Cretaceous red beds (see above) that occur in the vicinity and have been strongly faulted. The contact with the Triassic shale is marked by a red pedogenetic horizon, above which the reddish foraminiferal limestone are associated with radiolarian jasper up to 0.4 m thick. These are overlain by 250 m of gray limestone containing the rudists *Eoradiolites* sp. and *Biradiolites* sp., and foraminifera and algae, overlain by cherty limestone with *Pithonella* and foraminifera *Globotruncana linerana* *d'Orb*. The rocks are principally Turonian in age. Comparable outcrops on the western extension of the gray limestone contain Upper Cenomanian or Turonian rudists, as reported by Lang (1969) near Bamyan.

**Central Mountains**

*Neocomian (Berriasian–Hauterivian)*

At the beginning of the Cretaceous (Neocomian), the Central Mountains received a thick spread of continental or deltaic detritus of Wealden type (Montenat and Bassoullet, 1983), whereas along the axis of the platform, in a narrow subsiding trough, relatively deep-marine flyschoid sedimentation took place. Toward the southwest, the trough was limited to the Kandahar volcano-sedimentary basin (described later); northeastward, the trough closed, spoon-like near Kadjao. These deposits, whether continental or marine, are characteristically clastic marking a clear break with the predominantly calcareous Jurassic rocks. The change probably resulted from tectonic movements. However, sedimentation elsewhere was continuous with the Neocomian flysch trough seeming to coincide with the Upper Jurassic Oruzgan shale trough (see above).

Typical of the Wealden is the succession exposed at Tirin, 100 km north of Kandahar, where a thick terrigenous formation is separated from the underlying Jurassic limestones by an erosional surface. From the base upward, the sequence is as follows:

- A marine series about 200 m thick consisting of green shaly marls with interbedded sandstones and conglomerates resembling the flyschoid deposits of Oruzgan (see below).

![Figure 24: Massive Upper Cretaceous rudist-bearing limestones at Parandaz rest unconformably on possible Triassic-Jurassic shales and radioliters in the Turkman Valley, which is the possible eastern continuation of the Farah Rud Basin.](http://pubs.geoscienceworld.org/geoarabia/article-pdf/14/1/147/5444251/montenat.pdf)
• A continental or deltaic series of alternations of argillite, more-or-less sandy, with reddish or greenish sandstones, and conglomeratic beds with small-sized pebbles derived almost entirely from the re-working of beds of the same age. One reflection of this is the fan-like pattern of intraformational discordances. The sequence is about 300 m thick and several calcareous intercalations contain bryozoa and oyster debris. Volcanic tuffs have been identified in the lower part of the sequence (Paulsen, 1971). The red sandstones contain occasional specks of barite, and also some indeterminable reptilian debris that is the first evidence of reptiles in Afghanistan.

• Following without apparent break is a sequence of about 100 m of gray limestone. The limestone is sandy in the lower part, and according to Paulsen (1971) contains orbitolinids, suggesting an age no older than Barremian.

The geographic extent of the Wealden rocks is shown in Figure 28e. The total thickness probably exceeds 1,000 m. Minor marine intercalations (sandy limestones with oysters and bryozoa, and green shale) occur throughout the succession.

Between Tirin and Oruzgan, there is a lateral transition from the continental Wealden facies to a greenish pelagic flysch sequence (Figure 25a,b). The sequence has been tightly folded and has a marked schistosity. It is well exposed south of Oruzgan in the valley of the Tirin River. Here, there are in excess of 500 m of pale-green schistose pelites commonly with a matchstick-like fracture (Figure 25b) that alternate with fine, green sandstones having flute and groove casts on the base of individual beds. Fine-grained, gray-black, shaly limestone intercalations that contain aptychus fragments and other traces of ammonites, and impressions of thin-shelled lamellibranches, are interpreted as turbiditic, pelagic deposits; there are also bands of black chert nodules. Some of the calcareous turbidites contain small re-worked ooliths from the margins of the basin. The presence of *Phylloceras* (*Holcophylloceras*) cf. *calypso* and the debris of other ammonites indicate a probable Neocomian age. Additionally, calcareous microbreccias and olistoliths are gravity-flow deposits derived from uppermost Jurassic beds (Montenat and Bassoullet, 1983). Between Tirin and Kandahar, a little to the north of the Arghandab Dam, the flysch contains arkosic sandstones and conglomerates with re-worked sedimentary and metamorphic elements derived from the locally exposed Proterozoic Behsud Series. Uplift and exposure of the Proterozoic of the Central Mountains to the southeast acted as a source for the Neocomian sediments.

**Barremian to Upper Cretaceous**

Following the Neocomian, a new paleogeographic situation developed. The greater part of the Central Mountains and the northern homologous structure of Wakhan in the South Pamirs were emergent. Bordering this uplifted area to the northwest was the Farah Rud Basin, to the south the volcano-sedimentary basin of Kandahar, and to the southeast (in the Mokur and Misan area) was the Orbitoline Sea.

There is good evidence for this emergence. In the Kadjao Valley near Tezak, the Rhaetian Megalodon limestones are overlain with angular discordance by black, organic, micro-conglomeratic limestone up to a few tens of meters thick containing the *foram Protopeneroplis stiata*. This transgression dates from the latest Jurassic. The black limestone is overlain by pale-green, shaly marls with ammonite debris, identical, but much thinner (about 1,000 m) than the Neocomian Oruzgan Flysch. These deposits gradually gave way to an alternation of sandy, bioclastic limestones and variegated marls in which the foraminifera *Pseudocylammina lituus Yoko.*, *Pseudotextulariella salevensis*, Char. Bron. and Zan, and *Barkerina* *sp.*, and the algae *Actinoporella podolica* Guemb., *Boueina* *sp.*, *Cylindroporella* *sp.*, and *Suppilulixumella* *sp.* have been identified, indicating a Valanginian age (Bordet et al., 1976).

Overlying this succession is a 600-m-thick red and white continental conglomerate unit (Figure 26) that indicates the sudden and vigorous erosion of a nearby uplifted Permian-Triassic terrain. The synsedimentary re-working and frequent intraformational discordances provide evidence of the mobility within the depositional environment. A thick calc-alkaline volcanic suite (rhyolites, dacites, andesites) interspersed with terrigenous continental deposits overlies the conglomerates. Radiometric dating of volcanics from the upper part of the succession gives dates in the
Montenat

92 to 97 Ma range (Cenomanian) (Bellon et al., 1979). The underlying conglomerates are intruded and locally metamorphosed by a granodiorite dated at 100 Ma (Bellon et al., 1979). These continental conglomerates and volcanics represent the post-Neocomian Cretaceous (Blaise et al., 1982).

In the Aw Paran Trough, northeast of Oruzgan and 180 km from Kadjao, the succession is similar. The same red and white conglomerate with re-worked Permian-Triassic and Jurassic carbonates in the lower part and similar overlying subaerial andesitic and dacitic volcanics in the 100–82 Ma age range (Late Cretaceous) (Zimmerman, written communication, 1978; Bellon et al., 1979). Identical red and white conglomerates, with or without volcanics, occur at other locations within the Central Mountains, particularly near Maleston. Nowhere have marine beds been found in association with the conglomerates.

The marine platform deposits on the eastern border of the Central Mountains are typified by the succession near Mokur, described by Lapparent et al. (1970). Discordant upon Lower Jurassic limestone (see above) are gray conglomerates (125 m maximum thickness) fining upward, and containing

Figure 25: The Tirin flyschoid series (Late Jurassic-Early Cretaceous):
(a) Outcropping greenish shale with some interbedded turbidites;
(b) Matchstick-like aspect of the shales; they contain ammonites and black chert nodules.
reworked Permian-Triassic and Jurassic material (see Figure 14). Overlying the conglomerates are Barremian calcareous sandstones, black limestones, and gray marls with corals, Nerineas, bivalves (*Rugovercula mokurensis* (Termier and Termier, 1970), and orbitolinid debris. They are overlain by black or pink limestones, marl, sandstone, and some conglomeratic lenses, totaling about 200 m. On the basis of the contained fauna *Praerorbitolina* sp., *Rectodictyoconus* sp., *Dorothia* cf. *praeroxycosa* Moullade, and *Lenticulina* sp., a lower Bedoulian (Aptian) age is assigned. The top of the sequence consists of massive black Bedoulian limestone with rudists and abundant *Rectodictyoconus* sp. No post-Aptian deposits are present.

The Zarkachan Granite dated at 106 ± 4 Ma (Rb/Sr) (Debon et al., 1978, 1987) intruded the lower part of the Cretaceous succession. It forms part of the Arghandab granitoid massif that intruded and thermally metamorphosed the succession. Its emplacement was accompanied by gold mineralization near Mokur.

Near Misan, about 50 km to the west of Qalat, the Jurassic and Neocomian calcareous detrital series are succeeded by 1,000 m of massive gray limestone or occasionally dolomite, with orbitelines and rudists similar to those near Kandahar. They may be Albian-Cenomanian (Paulsen, 1971), but more probably Aptian, in age. These rudist and orbitoline limestones diachronously transgressed the southeastern border of the Central Mountains west of Misan, Abatu Chellah, and Tirin where limestones containing *Palorbitolina lenticularis* (Blum.) and *Orbitolina* sp. were deposited (Paulsen, 1971). To the west, the beds thin and become more detrital in character.

The essential characteristics of the volcano-sedimentary basin of Kandahar that lies on the southeastern margin of the Central Mountains were outlined in discussions on the Jurassic. The presence of Late Jurassic or earliest Cretaceous littoral carbonates north of Kandahar and of pelagic calpionellid limestones of Valanginian age in the center of the basin south of Kandahar, have already been noted.

The Barremian-Aptian paleogeography can be interpreted from the Kandahar-Spin Boldak section (Montenat et al., 1983) (see Figure 16b). To the northwest, the margin of the Kandahar Basin is fringed
by rudist and orbitoline limestones that, near Misan, are of Barremian-Aptian age perhaps extending into the Cenomanian (Kaever, 1967c), and resemble the Urgonian facies described by Prosorvsky (1990) (Figure 27) that are characteristic of the carbonate deposits on the limestone shelf of the Tethyan geosyncline.

On the southeast slopes of the Adi Ghar Massif (25 km northwest of Spin Boldak), a lateral passage from Aptian neritic limestone to pelagic deposits marks the recurrence of deep-water sedimentation to the southeast. The interfingering of the two facies is marked by olistoliths of coral and rudist limestone (displaced blocks or small slid blocks) and calcareous microbreccias with orbitolines. The pelagic deposits are analogous to those found northwest of the Adi Ghar Massif as micritic, platy limestones, more-or-less marly, with radiolaria, sponge spicules, and *Hedbergella*. The Chaman Fault passes close to Spin Boldak and marks the southeastern margin of the Kandahar Basin. Beyond the fault lies the Belouch Domain where Cretaceous deposits were probably initially intercalated with those of the Kandahar Basin (see below).

**Cretaceous of Wakhan**

In the Wakhan region of the southern Pamirs, the Lower Cretaceous shows a characteristic development of red molasse with some major volcanic intercalations up to 1,000 m thick (Vlasov, 1977). In Wakhan, a 300-m-thick succession of conglomerates, red siltstones, and marls that are discordant on the Carboniferous, are assigned to the Early Cretaceous, although no definitive dated material has been recorded.

**Cretaceous of Southeast Afghanistan:**

**Kabul Block**

The Cretaceous here is poorly defined. The Khinguil Series, whose Triassic and Jurassic members have already been described, are poorly fossiliferous, but the echinoid *Hemipeustes cf. persicus* and the ammonite *Promathildia (Clathrobaculus) cf. ziczac* Desh, from the upper part (Gazak limestones)

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**Figure 27:** The Adi Ghar Massif. The dark-colored volcanics are overlain by patchy, massive Aptian platform carbonates that contain orbitolinids, rudists, and corals.
indicate a Senonian age. According to Mennessier (1977), the Gazak limestones are of Late Triassic to Senonian age and are about 700 m thick without any notable discontinuities. No orbitoline beds, red conglomerates, or volcanics that are characteristic of the Central Mountains, are known. The two platforms therefore underwent quite different tectonic-sedimentary evolutions. Conversely, Senonian (Coniacian–Maastrichtian) ammonites are unknown in the Central Mountains.

**Cretaceous of the Allochthonous Series**

The Khost ophiolite nappe, deep-sea deposits of the Rokian Series, the Ahmadkhel Series, and the Kotagae Series comprise the Allochthonous Series (see Figures 5 and 29).

**The Khost ophiolite nappe.** The nappe and its volcano-sedimentary cover are thrust toward the Indian Foreland. The volcano-sedimentary rocks consist of tuffs and pyroclastic breccias associated with radiolarites, olistoliths, and calcareous microbreccias. The latter contain a microfauna of *Flabellamina, Trinocladus, Marinella lugeoni* Pfen and orbitolines(?), which Cassaigneau (1979) interpreted as earliest Cretaceous, Aptian-Albian or even Cenomanian. The same age is proposed for the volcanic basement (the Khost Ophiolite) that Tapponnier et al. (1981) regarded as ocean-floor material, or as a sea mount thrust with the latter.

This assumption must be treated with some caution for, apart from the fact that the volcano-sedimentary sequence is in tectonic contact with the ophiolite, the accompanying microfauna (surprising in an oceanic environment), can only be explained by the incorporation of reworked material from the adjacent platform. It is therefore not clear that the fossils are contemporaneous with the surrounding sediment; they fix only the lower age limit.

**Deep-sea deposits.** The deep-sea deposits of the Rokian Series contain Triassic and Jurassic units. Keaver (1967a) assigned a Jurassic or Early Cretaceous age based on microfauna discovered near Ali Ghal, with *Trocholina, Paratrocholina, Munieria*, and *Actinoporella podolica* (Alth.). About 30 km to the west, in the Dobardi valley, Mennessier (1970) studied a section of the Rokian Series. The lowest member consists of an alternation of gray shale and black radiolarian limestone 1,600 m thick, ranging in age from Triassic to Early Cretaceous. Locally, Middle Triassic Doanellids have been reported. This sequence is overlain by additional gray shale, basalts, radiolarites, and gray lenticular limestone with a splintery fracture. Some of the limestones contain *Orbitolina cf. kurdica* (Rens.), *O. cf. discoidea* Gras, and *Solenopora* of Late Aptian to Early Albian age; others contain *Paratrocholina lenticularis* (Hens.), *P. oscillensis* (Oberh.), and fragmentary radiolarites to which a later Cenomanian-Turonian age has been assigned. Pillow lavas are common in the Cenomanian-Turonian association. In the highest member, 2,000 m of shale enclose chaotic blocks of periodotites, radiolarites, and olistoliths of Permian limestone derived from the Altimour limestone sequence. Mennessier assigned a Senonian age to this olistostrome, which is overlain by Santonian-Campanian limestone.

The fauna described (Orbitolinids and algae) indicate re-sedimentation in a deep-water environment that existed at the time of deposition of the Rokian Series. The orbitolines were not derived from the Kabul platform, or from the Altimour limestones where they appear to be absent. The most probable source is the eastern margin of the Central Mountains.

**The Ahmadkhel Series.** The Series crops out between Gardez and Alikhel south of the outcrop of the Rokian Series and on the southeastern slope of the Altimour Massif, and was briefly described by Cassaigneau (1979). It is probably equivalent to the upper part of the Rokian Series described by Mennessier (1970), but extends stratigraphically higher in the Senonian since micritic limestones contain a Late Campanian or Maastrichtian microfauna of *Globotruncana stuartiformis, G. limneiana tricarinata*, and *G. cf. confusa*. The Ahmadkel Series is overlain by an olistostrome of blocks of pillow lava, radiolarites, and Jurassic limestone similar to that reported by Mennessier (1970). The matrix has a Maastrichtian microfauna with *Globotruncana stuarti conica, G. stuart, G. limneiana, G. gansseri,* and *Gublerina cuvillieri*. It therefore seems certain that the Rokian Series is terminated by a chaotic Late Cretaceous assemblage that Cassaigneau (1979) called an ‘ophiolitic mélange’. 
Overlying the Permian to Jurassic limestones of the Altimour Massif are gray limestones, often dolomitized. They contain indeterminable fragmentary ammonites, remains of rudists (perhaps of the genus *Toucasia*), and *Chaetetes*-type organisms, which suggest that the upper Altimour limestones may be of Early Cretaceous age. According to Cassaigneau (1979), the massive Altimour limestones are simply large olistoliths in an ophiolitic mélange.

**Kotagae Series.** The facies of the Kotagae Series have such close similarities to those of the Rokian Series (see above) that the same Triassic to Cretaceous? stratigraphic limits have been suggested, although the presence of the Cretaceous has not been biostratigraphically established. Between Kabul and Sarobi, what is possibly the upper part of the Kotagae Series is a chaotic mixture of blocks of ultramafic rocks, red radiolarites, and calcareous olistoliths, some of which are of Jurassic age, in a green argillaceous matrix. The appearance of this colored mélange accentuates the similarity with the Rokian Series, namely, the olistostrome or ‘ophiolite mélange’. According to Mennessier (1977), the Kotagae Series is overlain discordantly by the Ali Pack Bel limestones that contain Santonian–Campanian microfossils such as *Globotruncana* ex gr. *Lapparenti* (Figure 5). It is possible that these limestones may include beds of Maastrichtian age. These are therefore considered as an exact analogue of the limestones overlying the Rokian Series.

**PALEOGEOGRAPHIC EVOLUTION**

The principle characteristics of Mesozoic paleogeographic evolution are outlined in accordance with the main geologic regions (see Figures 1, 5, and 28).

**Northern Afghanistan**

From the earliest Triassic (Scythian), the North Hindu Kush marine trough formed within the previous Carboniferous-Permian carbonate platform (Figure 28a). The faulting that gave rise to the basin followed a tensional phase, and the relative narrowness of the basin with respect to its length, the nature of the sedimentary fill, and in particular, the important role of volcanic activity, all testify to the tectonic nature of this rifted basin. Subsidence was active in the North Hindu Kush Rift and the sedimentary deposits are up to 6,000 m thick. Rapid facies and thickness variations, in addition to intraformational discordances, witness the play of the faulted blocks. The rift basin did not develop beyond the early stages and was filled by continental deposits (the Baiera Beds) during the Rhaetic. Its evolution was terminated during the Late Triassic Eocimmerian Orogeny.

Throughout the Triassic, the northern part of the Afghan Turkestan region remained emergent. Red terrigenous sediments were deposited widely in Central Asia. Along the southern border of this vast continental area, pelitic-arenaceous paralic sediments with marine carbonate intercalations mark the transition to the North Hindu Kush Rift Basin (Figure 28a).

Biogeographically, the trough and its northern margin, although distant from the central corridor of the Triassic Tethyan Ocean, received a typical series of widely spread Tethyan or Alpine fauna (ammonites, pelagic molluscs and corals). The North Hindu Kush Rift also contains a Germano-type molluscan fauna with *Myophoria* (Farsan, 1979). The previously known distribution of this fauna in the Middle East (Sinai and Jordan) led to the conclusion that it spread along the southern margin of Tethys via Spain and North Africa. Its presence north of the Hindu Kush along the border of the Turan Platform now suggests a north-Tethyan migration route via Turkey and the Caucasus (see Farsan et al., 1982). In fact, once the environmental connections were made possible, the ‘Germanic’ fauna became established on both shores of the Tethyan Ocean (see Figure 30).

Following Eocimmerian folding in the Late Triassic-Early Jurassic, northern Afghanistan became emergent, and was covered by an abundant Angara-type flora that formed coal deposits of Middle Jurassic age. The same coal-type facies was widespread in Central Asia and Indochina. Animal life is fleetingly evoked by vertebrate footprints found in Band-e Bayan that resemble reptile tracks from the Jurassic of China (Lapparent and Stöcklin, 1972). Marine incursions in the Middle and Late Jurassic were from the north, from Central Asia, a region that shared the same paleogeographic history as northern Afghanistan during this period (Figures 28b,c,d).
During the Cretaceous, northern Afghanistan formed the southern part of a large basin that extended northward into Tadjikistan. The Neocomian (Berriasian–Hauterivian) ‘Red Grits’ sandstones and conglomerates were deposited following renewed tectonic activity (Neocimmerian: end-Jurassic–earliest Cretaceous), and quite possibly a climatic deterioration as shown by the disappearance of vegetation and the onset of oxidizing conditions. The most extensive development of the Red Grits is on the northern slopes of the Hindu Kush and in Badakhshan where the rejuvenated relief supplied the detrital sediments. Toward the north, the sediments thin out and change into variegated gypsiferous clays that indicate Neocomian marine incursions as identified north of the Amu Darya River (Figure 28e).

This marine transgression from what is now Tadjikestan spread the ‘Green Beds’ over northern Afghanistan during the Aptian-Albian to Lower Senonian (Figure 28f). The various units progressively thin out and eventually disappear to the southeast and south on the flanks of the emergent Hindu Kush and Badakhshan region, and surround an emerged ridge where the reduced sequences of Band-e Turkestan occur. The development of increasingly calcareous or terrigenous deposits marks the proximity of the shoreline. This North Afghan Basin, closed to the south, was not in direct communication with the Farah Rud Domain from which it was partly separated by the emergent Hindu Kush and Band-e Bayan ridge.

During the same Barremian-Aptian time interval, sedimentation in the northern Farah Rud Basin was quite different. Orbitolinids are practically unknown in northern Afghanistan. Nevertheless, as Schroeder and Lapparent (1967) have noted affinities between the Barremian orbitolines of western Turkmenistan and those of Farah Rud, a connection must have existed farther to the northwest, or northeast from the Karakorum (Desio, 1960; and Desio and Martina, 1972) between this basin and Central Asia. This connection must have lain beyond the Band-e Turkestan ridge, so leaving the basin of Afghan Turkestan, east of the ridge, relatively isolated.

The end of the Cretaceous (Campanian-Maastrichtian) marks another important paleogeographic stage. The Band-e Turkestan ridge was submerged from Santonian times and the transgression affected the northern and western margins of the Hindu Kush during the Campanian. It is possible that during this time a connection was established with the Panjaw region (Farah Rud Domain). These marine conditions persisted into the Neogene in northern Afghanistan, whereas the central and southern parts were emergent.

**Band-e Bayan and the Western Hindu Kush**

Welded to one another since the end of the Paleozoic, during most of the Mesozoic Band-e Bayan and the western Hindu Kush behaved as a single unit, either as an east-west elongated platform, or an emergent chain. It marked the main paleogeographic boundary between northern Afghanistan and the regions to the south.

During the Triassic, sedimentation in Band-e Bayan was reduced or absent, and the presence of bauxitic horizons is evidence of emergence (Figure 28a). Similarly, the Central Pamirs, equivalent to Band-e Bayan, had the same environment. The western Hindu Kush, also barren of Triassic deposition, formed an emergent zone to the south of the North Hindu Kush Rift Basin. It was the site of granodiorite emplacement, with the ages of the emplaced plutons ranging from 235 to 200 Ma, with a peak around 210 Ma in the Late Triassic (Debon et al., 1978; 1987) (Figures 1 and 28a).

From the beginning of the Jurassic, Band-e Bayan was incorporated into the Farah Rud Basin, of which it formed the northern margin. It was a subsiding, occasionally reefal, passive margin where thick detrital or calcareous sediments accumulated. The sequence includes carbonate deposits that pass southward into the Farah Rud flysch. The Central Pamirs (the median platform of Vlasov, 1977) was also covered by detrital or calcareous sediments laid down in a shallow sea or even continental environment (Ovechkin, 1959) (Figures 28b–f).
Figure 28: Distribution of Mesozoic sedimentary facies in the geostructural domains of Afghanistan

- **Figure (a): Triassic**
- **Figure (b): Lower Jurassic**
- **Figure (c): Middle Jurassic**

| Color Code | Description |
|------------|-------------|
| Continental or emerged deposits (a) to (f) | |
| Continental deposits | |
| with shallow-water marine intercalations (e) | |
| Triassic rift deposits (a) | |
| Platform carbonates; inner, outer (a–f) | |
| Flyschoid deposits (a); “green beds” transgression (f) | |
| Deep-marine (b–f) | |
| Ophiolite complex (a) | |
| Neritic deposits: (incl. continental and lagoonal (c); Carbonate and clastics (f) | |
| Volcano-sedimentary deposits (Kandahar Basin) (d,e) | |
| Coal lenses (b,c) | |
| Volcanics | |

Key:
- AF = Akhbaytal Fault
- CF = Chaman Fault
- HF = Herat Fault
- HF = Helmand Fault
- KF = Kadjao Fault
- SF = Sarobi Fault

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Farah Rud Basin

The younger Paleozoic to early Mesozoic rocks in the Turkman Valley provide some interesting insights into the early stages of the development of the Farah Rud Basin if, as is generally thought, they belong to the same paleogeographic unit. They form a 1,000-m-thick sequence of predominantly shaly beds dated as Permian and Triassic but probably Carboniferous to Jurassic. Continuous sedimentation during this long period indicates a gradual deepening of the depositional environment: shales with Spirophyton are regarded as Carboniferous; Permian to Triassic shale and turbiditic calcareous microbreccias; and Triassic green shale and radiolarites. They provide a record of sedimentation occurring in a basin developing on the southern margin of Band-e Bayan and the Hindu Kush. Some of the re-worked microfossils in the calcareous microbreccias provide evidence of the northerly provenance of the turbidites from the uncovering of the late Paleozoic carbonate platform of the Hindu Kush.

Ultramafic massifs interpreted as remnants of oceanic crust, together with deep-water sediments (including radiolarites), and the presence of submarine basalts, are evidence for a phase of oceanic opening of the Farah Rud Basin in the Triassic (Figure 28a). Large olistoliths of Permian-Triassic carbonates incorporating large quantities of pyroclastic material may have formed by erosion of the Central Mountains Platform on the southern margin of the Basin. A Triassic calc-alkaline magmatic belt north of the Farah Rud and Rushan Pshart domains is probably related to a northward subduction of the oceanic floor beneath the Hindu Kush and Central Pamir continental blocks.

Deep-water sedimentation continued during the Jurassic (Figures 28b–d), but changed in character as the volcano-sedimentary sequence with its olistoliths was followed by development of a sandy-argillaceous flysch with rare intercalated micritic limestones and no eruptive rocks. These beds are poorly dated, as only generalized Late Jurassic and Neocomian (Berriasian–Hauterivian)-age beds have been identified. Nevertheless, the main features of a Jurassic basin profile can be established. The northern margin against the Band-e Bayan Basin was strongly subsident and received a thick series of littoral sediments. The basin deepened to the southeast, and near the border of the Central Mountains a thick monotonous sequence of Helminthoid flysch accumulated. The detrital material brought into the basin by turbidity flows does not appear, for the most part, to have been derived from the northern Band-e Bayan margin. A southern provenance, from the northwestern edge of the Central Mountains that dominates the basin and where the Proterozoic basement was exposed more-or-less continuously since the beginning of the Jurassic, for example the Behsud zone, seems more plausible (Figure 28b–d).

Paleogeographically, the Farah Rud Basin belongs to the Tethyan Domain and in the Neocomian it received a calpionellid fauna identical to that of the western Mediterranean. At the end of the Neocomian, the Farah Rud Basin was closed and its deposits folded and metamorphosed (see Figures 6b and 23). This tectonic event was followed by a major erosional phase.

Beginning in the Barremian, the sea again occupied the Farah Rud Basin, transgressing progressively from west to east (Figure 28f). This time the sea was shallow and its fauna consisted of widespread orbitolines and biothermal forms, such as algae, corals, and rudists. The sedimentation pattern is marked by both a terrigenous influx and carbonate deposition.

Subsidence remained active, particularly in the western part of the basin where deposits total several thousands of meters. Intense volcanic activity characterized the early phases (Barremian-Aptian) with tuffs, airfall andesitic and rhyodacitic breccias. The relief of the Band-e Bayan Block again marked the northern margin of the basin. Toward the east, the sea appears to have made only brief incursions east of the longitude of Panjaw. Toward the south, by rounding the largely emergent Central Mountains, the sea connected with the Kandahar Basin. With these limits, the Farah Rud Basin formed a large gulf open to the west but strongly constricted to the east.

Late Cretaceous evolution of the basin is poorly known. During the Cenomanian, the sea appears to have retreated to the western part of the basin. Turonian and Senonian beds were deposited in the northeastern part of the basin near Panjaw, Parandaz, and Bamyan following a period of post-
Early Cretaceous deformation (see Figure 6b). They contain rudists in the Parandaz and Panjaw areas and pelagic foraminiferal *Globotruncana* deposits with the taxonomically problematic *Pithonella* in the Campanian. Such deposits indicate a deepening of the sea with respect to the shallow-water orbitoline environment. It is not known whether or not these deposits covered the whole of the Farah Rud Basin.

**Central Mountains**

The Central Mountains have acted as a platform since the Paleozoic, and movement along generally northeast-oriented faults active since the early Paleozoic (or even the Proterozoic) controlled the distribution of isopic sedimentation. At various times during the Mesozoic, as in the Paleozoic, a subsiding trough elongated northeast developed along the axis of the platform (Desparmet and Montenat, 1972; Karapetov et al., 1971; Vachard, 1980) (Figures 28d, e and Figure 33).

In the Central Mountains, carbonate deposition continued into the Triassic (Figure 28a) from the Permian. Triassic carbonates occur as olistoliths within the volcano-sedimentary sequence of Farah Rud. Tidal-flat deposits, such as algal mats and desiccation breccias, were deposited on the western part of the platform. Their thickness, at about 1,000 m, implies a remarkably close balance of subsidence and deposition maintained over a 30 m.y. period during which neither continental nor desiccation episodes can be detected. Toward the eastern part of the Central Mountains the deposits show a progressively more open-marine character with vermicular limestone and the presence of bivalves (*Claraia*) and ammonites typical of the pelagic Tethyan environment. The marine environment was probably controlled by the gradual eastward tilt of the platform (see Figure 33), due to movement on step faults cutting the basement. At this time, the Kabul Block was probably attached to the Central Mountains Platform, and formed the deepest external part of the platform. Volcanic activity was restricted to fissure basalts along the western border of the Central Mountains and to mafic green tuffs in the Kabul Block.

Depositional conditions became more uniform in the Late Triassic with the deposition of the Rhaetian Megalodon limestones (Central Mountains and Kabul Block). The boundary between the Triassic and Jurassic is marked by a tectonic episode that decreases in intensity from west to east. Terrigenous sedimentation and angular discordances are found in the west, whereas a continuous detrital carbonate sequence was deposited on the eastern margin of the Central Mountains, and uniform carbonates on the Kabul Block.

From the beginning of the Jurassic (Figures 28b and 33), the emergent relief of the western margin of the Central Mountains provided a clastic source area for the terrigenous flysch deposits deposited in the Farah Rud Basin and over the platform itself. In the west, the platform remained tilted toward the east and the Beloutch Basin during the Early and Middle Jurassic (Figures 28b, c). An important paleogeographic change occurred during the Late Jurassic, with an Oxfordian hiatus (see Figures 13 and 33d, e) following which the platform was differentiated into deeper and shallower sedimentation areas. A zone of sub-reefal carbonates followed the formation of bauxite during an emergent period at the beginning of the Late Jurassic (Surkhbed) (Figure 15).

A profile of the Central Mountains during the latest Jurassic shows the following units, from northwest to southeast (Figure 28d):

- Emergent relief on the western margin dominating the Farah Rud Basin; shallow-water carbonate and clastic deposits fringing this upland area.

- The narrow Tirin-Oruzgan Trough (see Figure 33) with pelagic shale deposits similar to the Spiti Shales of the Himalayas.

- Emergent relief where the Proterozoic basement crops out on the right bank of the Arghandab River.
On the southern margin of the Central Mountains, the Kandahar volcano-sedimentary basin (see Figures 16a,b) developed during the Late Jurassic, later evolving into a marginal basin during the Early Cretaceous (at about 100 Ma) on the margin of the Beloutch oceanic domain.

The paleogeographic diversity of the Central Mountains, linked to large-scale vertical movements contemporaneous with magmatic activity along its southeastern margin, can be related to the evolution of the adjacent oceanic domains (Figures 31 and 33).

The Neocomian (Berriasian–Hauterivian) is marked by a decrease in carbonate deposition and a corresponding increase in clastic sedimentation. Marine sedimentation was restricted to an elongate flyschoid trough, similar to that which existed during the Late Jurassic along the axis of the Central Mountains (Figures 28d,e and 33d). It was connected in the southwest to the volcano-sedimentary basin of Kandahar. Over the remainder of the emergent platform were spread sheets of Wealden detritus, derived from the erosion of the uplifted areas.

From Barremian-Aptian times, the Central Mountains were emergent and shallow transgressions from the Orbitoline Sea in the Kandahar Basin were restricted to the eastern and southeastern margins (Mokur, Misan). Within the platform, the rejuvenation of relief-enhanced erosion and thick red conglomerates (Red Grits) accumulated in grabens. Calc-alkaline volcanism consisting of ash-fall tuffs and dacitic and andesitic lavas, began at about 100 Ma in several of these grabens, such as the Kadjao and Aw Paran regions. It was contemporaneous with the emplacement of the Arghandab granodiorites along the southeastern margin of the Central Mountains and plutons of minor importance along the northwestern margin (Kadjao) (see Figure 33f).

The evolution of the Kandahar Basin during the Early Cretaceous was marked by the southeasterly progradation of its northern edge. This resulted in the progressive emergence of the more northerly sections (north of Kandahar) and the southerly displacement of the deepest part of the basin (south of Kandahar). Within the latter, pelagic carbonates with calpionellids, then radiolaria accumulated. Interbedded allodapic carbonate beds were deposited from turbidity flows of penecontemporaneous littoral carbonates (Orbitoline limestone). Submarine volcanic activity migrated in the same southerly direction and persisted toward the southeast.

Southeast of the deep volcano-sedimentary basin, a sub-emergent volcanic island arc developed to form the Adi Ghar Cordillera that was still active at the beginning of the Aptian, and then overlain by shallow-water or reef-type platform carbonates (see Figure 27). Beyond this island arc another deep basin, the Beloutch Basin, opened.

The volcano-sedimentary rocks of the Kandahar Basin are buried beneath surficial deposits of the Seistan Desert south of Kandahar, but reappear to the south of the desert in Pakistan. There they are known as the Sinjrani Volcanic Group of the eruptive zone of the Baluchistan Basin in the Chagai and Rashok regions (Ibrahim Shah, 1977). The volcanic complex is overlain, discordantly in part, by Maastrichtian rudist- and orbitoid-bearing limestones containing terrigenous units (the Ramai Formation). Toward the north along the western margin of the Seistan Desert, an analogous volcano-sedimentary sequence containing andesites and dacites and overlain by Alban-Aptian or Cenomanian rudist limestones, extends to just south of Herat near Anardara (Cizancourt et al., 1937). From there, this essentially Early Cretaceous basin connects with the Farah Rud Basin where the sediments are of a more littoral or even continental character, but still contain evidence of calc-alkali volcanism. This branch of the Kandahar volcano-sedimentary basin follows a major lineament, the Hari Rud Fault that separates the Central Mountains from the Lut Block in eastern Iran. The pattern of volcanic activity emphasizes the exceptional role of magmatism in the Cretaceous history of Afghanistan (Figures 31 and 33). Late Cretaceous deposits, for example the Campanian-Maastrichtian marls and limestones, widely developed in other regions are not present in the Central Mountains due to emergence (Figure 33g).

The Central Mountains Domain extends to the northeast into the Wakhan and Nouristan regions of the Southern Pamirs. Here the Triassic differs from that of the Central Mountains by the predominantly terrigenous, non-carbonate nature of the sediments (shale and quartzite) in Nouristan, whereas farther to the east in the Karakorum, the Triassic reappears in a carbonate facies comparable with that.
found in the Central Mountains. In contrast, the facies of the Early and Middle Jurassic of Wakhan closely resemble those of the Central Mountains. The Late Jurassic has not been identified; however, Early Cretaceous red conglomerates and granitic intrusions are present.

To the southwest, the Seistan Desert separates the Central Mountains from the Lut Block of Iran that presents a different structural and stratigraphic history. As for other paleogeographic and structural domains in Afghanistan, such as the Band-e Bayan and Farah Rud basins, their western limits seem to be the trace of the Hari Rud Fault that corresponds approximately with the Afghanistan-Iranian border.

Southeastern Afghanistan

Within southeastern Afghanistan, the two major tectonic groupings are the autochthon of the Kabul Block and the various allochthonous units that consist of pelagic and ophiolitic elements (see Figure 5). The original paleogeographic arrangement of these units has resulted in contradictory hypotheses (Figure 29).

According to Mennessier (1977), the allochthonous units were transported toward the north and northeast. Figure 29a shows the paleogeographic arrangement.

Cassaigneau (1979), Mattauer et al. (1978), and Tapponnier et al. (1981) took the opposite view. Their hypothesis requires that the initial vergence of the allochthonous units was directed toward the south and southeast, in which case the paleogeographic arrangement is as shown in Figure 29b. In this model, the Altimour massifs do not represent a paleogeographic unit, but are regarded as huge exotic blocks similar to the ‘Oman exotics’ (Searle and Graham, 1982). The sedimentary and ophiolitic units of Khost-Rokian are largely thrust over the Indian Foreland (Waziristan and Zhob ophiolites).

Since polyphase earthmovements were largely tangential since the end of the Cretaceous, part of the uncertainty vis-à-vis Mennessier (1977) is caused by the possibility of retrothrusting directed toward the northwest.

Figure 29: Paleogeographic and structural hypotheses for the Mesozoic of southeastern Afghanistan: (a) After Mennessier (1977); (b) After Cassaigneau (1979), Mattauer et al. (1978), and Tapponnier et al. (1981); (c) This study.
This paper proposes a third hypothesis as shown in Figure 29c. From northwest to southeast, the major tectonic elements are as follows:

- Central Mountains Platform.
- Kandahar marginal basin and volcanic arc.
- Ocean basin floored by the Logar Ophiolites, later thrust on to the Kabul Block.
- Kabul Block carbonate platform, possibly with the Altimour limestone series on its southeastern margin.
- The Kotagae Marginal Basin series: a suite of basaltic and andesitic volcanics. These are clearly not an oceanic suite, but probably show affinities with an island-arc suite associated with a marginal basin (cf. Kandahar). Included olistoliths were derived from the Kabul Block or Central Mountains.
- Khost-Rokian Basin whose oceanic floor is formed by the Khost Ophiolites and their cover by the volcano-sedimentary sequence of Khost-Rokian.
- Peri-Indian Platform.

In all the hypotheses, the Kabul Block appears as a micro-craton for which no paleogeographic continuation is known. The oceanic area floored by the Logar Ophiolites between the Central Mountains and the Kabul Block was probably narrow. Fault movements since the mid-Eocene (perhaps earlier) caused important sinistral displacements between the Central Mountains and the eastern regions.

**Kabul Block**

The Kabul Block was the site of carbonate deposition that persisted with no significant interruption from the Late Permian to Late Cretaceous. The similarities between the Upper Permian of the Kabul Block, both lithostratigraphic and biostratigraphic, and the Central Mountains led Vachard (1980) to assume that the two domains belonged to a single unit.

The Triassic facies of the Kabul Block are comparable with those on the eastern border of the Central Mountains. They were deposited in an outer platform environment close to the continental slope, and consist of ammonite- and *Claraia*-bearing limestones in a sequence containing intraformational breccias. The presence of green mafic tuffs in the Upper Triassic suggests fissure eruptions similar to contemporaneous volcanics elsewhere in the Tethyan domain. It is possible that the Altimour limestones were initially deposited on the continental slopes of the Kabul Block. They represent a Lower Triassic condensed pelagic series of the ‘ammonitico rosso’ facies. Middle Jurassic sedimentation was of shallow-water type, after which the platform began to subside with deposition of the more pelagic deposits of Late Jurassic age, such as belemnite-bearing limestones.

Following the deposition of the Upper Triassic Megalodont limetones, the evolution of the Kabul Block deviated from that of the Central Mountains (Figures 28b-d). Cimmerian tectonic events are unknown in the Kabul Block and there is no episode of infra-Lower Jurassic or Cretaceous detrital deposition such as characterized the Central Mountains. In addition, no traces of the orbitoline and rudist beds, so well developed around the margin of the Central Mountains are present. Cretaceous magmatic activity is also absent, so there is reason to consider that the Kabul Block was detached from the Central Mountains in the Jurassic and has evolved since then independently within the Belouch Domain.

Cretaceous depositional environments are difficult to define because of the scarcity of fossils in what may have been an outer platform environment.
Allochthonous Units

The rocks forming the allochthonous units had a bathyal character throughout the greater part of the Mesozoic; the pelitic, radiolarite facies appear comparable, although they probably belong to different environments (Figures 28a–f and 29).

The Kotagae Series contains olistoliths derived in part from the Kabul Block and Altimour Series and an andesitic Cretaceous complex. These observations suggest that the Kotagae Series was deposited in a marginal basin or island-arc environment bordering a continental block (Central Mountains or Kabul Block). Some platform limestones (Orbitoline and Turonian limestones) included within the series may be olistoliths that were transported by gravity slides from carbonate-capped seamounts, for example in the Kandahar volcano-sedimentary basin.

The Khost-Rokian Series is considered to be a volcano-sedimentary sequence that accumulated on an ocean floor. The Khost Series is a particular flysch-type facies of the Rokian, rich in turbiditic, calcareous microbreccias (Triassic?-Jurassic) and containing re-worked platform carbonates. This type of deposit resembles in part, the sedimentary rocks in the Hawasina Nappes in Oman. The Khost calcareous flysch probably occupies a marginal location in the Belouch Basin, adjacent to a platform belonging to the north Tethyan margin (Central Mountains or Kabul Block). The Altimour massifs may represent exotic blocks, numerous examples of which border the Alpine Tethys from Sicily to Timor. Their depositional environment is still debatable. They may represent seamounts or deposits of a subsiding continental block. They were perhaps incorporated into the pelagic sediments as olistoliths at the end of the Cretaceous. Their emplacement marks the beginning of earth movements that ended the evolution of the Belouch Basin.

In addition to the sedimentary and volcano-sedimentary deposits, the southeastern domains of Afghanistan include two distinct ultramafic complexes, the Khost and Logar ophiolites, both clearly Mesozoic but still poorly dated. The Khost Ophiolites (Triassic?-Cretaceous) belong to the same sequence as the Waziristan and Quetta (Zhob) ultramafics (Andrieux and Brunel, 1977), thrust over the Indian Foreland. They represent the ocean floor of the Khost-Rokian Basin between the Indian continent and the Kabul Block. The Logar Ophiolites (Oedraogo, 1985), well known because of their chrome and copper deposits, were thrust over the Kabul Block. They represent the floor of another basin, perhaps originally lying between the Central Mountains and the Kabul Block.

MESOZOIC OF AFGHANISTAN AND PLATE TECTONICS

In order to understand the evolution of Afghanistan during the Mesozoic in relation to its plate tectonic development, it is necessary to examine the preceding late Paleozoic.

During the Carboniferous, the warm-water fauna of northern Afghanistan (fusulinids, corals) contrasted with the less-varied, more temperate faunas of the Central Mountains and Band-e Bayan (Montenat, Vachard and Termier, 1977; Termier and Termier, 1977; Vachard, 1980). At that time, the last two regions were probably still part of the Gondwana. Nevertheless, in Wakhan and in the Himalayas, Carboniferous flood basalts indicate tectonic extension within this part of Gondwana, perhaps related to the opening to the Belouch-Indus-Tsang Po Basin.

Northern Afghanistan was part of the so-called Angara Block within the Eurasian Plate (Termier and Termier, 1977), and therefore lay on the northern Tethyan margin. An ocean (Paleo-Tethys) of unknown width (Figure 30) must have separated the two disparate faunal zones. The outcrops of strongly serpentine ultramafic rocks (Waras Ophiolite) that border the Herat Fault, and the Rushan Pshart Fault separating the southern and central Pamirs, may be a remnant of this ocean that was subducted near the end of the Paleozoic (Stöcklin, 1977).

At the beginning of the Permian (Asselian-Sakmarian), weak indications of the glacial and periglacial stages that occurred in parts of Gondwana are perceptible in the Eurydesma fauna of the Central Mountains. From the Artinskian onwards, a warm-water carbonate platform developed in northern
Afghanistan, the Central Mountains and the Kabul Block, in the so-called Fusulinid Sea. At that time, the Central Mountains were still close to parts of Gondwana, for example, Oman (Montenat, Lapparent et al., 1977).

Concurrently, a subsiding basin in which radiolarites and turbidites were deposited (in the Turkman Valley, for example), was formed between the Band-e Bayan and the Central Mountains (Montenat and Vachard, 1980), possibly in the Farah Rud oceanic basin. Between the Central Mountains and the Indian Platform, a poorly defined basin probably formed in the late Paleozoic (Vachard, 1980) and later gave rise to the Mesozoic Beloutch Basin.

**Mesozoic Oceanic Belts**

**General Mesozoic Setting**
Plate-tectonic processes controlled the tectonostratigraphic and magmatic evolution of Afghanistan in the Mesozoic (Figure 31). As a result:

- Carbonate platforms and alternating pelagic-bathyal troughs formed between the two great continental masses of Eurasia and Gondwana (Figure 30) where sediments were mostly terrigenous and continental.
- Ophiolitic complexes were linked to these pelagic basins.
- Calc-alkaline magmatism (plutonic and volcanic) was particularly well-developed during the Triassic and Early Cretaceous along the continental margins of these basins on the southern margin of Eurasia (Hindu Kush) and the Central Mountains Block.
• Phases of major tectonic activity became progressively younger from north to south (Bassoullet et al., 1980; Boulin, 1990); for example, the Eocimmerian (Latest Triassic–earliest Jurassic) of the North Hindu Kush Rift, the Neocimmerian (end Jurassic–earliest Cretaceous) of the Farah Rud Basin, and the end-Cretaceous and Tertiary Alpine earth movements of the Beloutch Basin.

Two major oceanic belts are recognized (Figures 30 and 31): the northern Farah Rud Basin and the southern Beloutch Basin separated by the continental block of the Central Mountains. Petrographic data on the Afghan ophiolitic complexes are limited (Mattauer et al., 1978; Cassaigneau, 1979; Ouedraogo, 1985). The width of the oceanic belts cannot be determined since no paleomagnetic data are available (Patriat et al., 1982; Westphal and Pozzi, 1984).

Figure 31: Chronodiagram of the main Mesozoic geodynamic events.
Cimmerian Terranes (Latest Triassic to Earliest Cretaceous)

A characteristic feature of the Mesozoic Tethyan region is the presence of continental blocks (microcontinents or terranes) (Figure 30) of the major Eurasian and Gondwanan landmasses (Sengör, 1984; 1990; Stöcklin et al., 1989; Stampfli et al., 2001). They include the Iranian Alborz, Yazd and Lut blocks, and the Afghan Helmand Block (the continental basement of the Farah Rud Basin), and the Central Mountain and Kabul blocks. They correspond to fragments of Gondwana inserted between the Paleo- and the Neo-Tethys during the Mesozoic. These blocks acted with relative autonomy during the evolution of the Tethys.

A Major Mesozoic Paleogeographic Break: the Hari Rud Fault

The Mesozoic geodynamic domains and tectonic events in Afghanistan can be correlated with those farther east in the Pamirs, Himalayas and Tibet (Bassoullet et al., 1980). Correlation with areas in Iran to the west is difficult for the Mesozoic, though satisfactory for the late Paleozoic (Vachard, 1980). In particular, the North Hindu Kush Rift, the Band-e Bayan axis, the Farah Rud oceanic basin, and the Central Mountains have no direct continuation in Iran. The structural map of Stöcklin (1977) demonstrates that these paleogeographic and structural units are bounded by the major sub-meridional Hari Rud Fault about 100 km west of Herat. The fault separates the various Cimmerian terranes (Figures 1 and 30) and approximates to the line of the Afghanistan-Iran border. West of the Fault is the Lut Block that forms a unit independent of both Afghanistan and other parts of Central Iran. Tectonically, the Eocimmerian and Neocimmerian phases show different timing and structural behavior in central Iran and Afghanistan (Stöcklin, 1968; 1972). In contrast, the Belouctch oceanic belt and its southerly continuation (Zhob and Bela in Pakistan) correlate approximately with the oceanic units of Oman and Zagros (Figure 30).

Farah Rud Zone

The Farah Rud Basin was probably part of a more extensive Neocimmerian oceanic belt, discontinuous from Afghanistan to Tibet and Burma that resulted from the break up of peri-Gondwana. The Farah Rud (Figures 6b and 31) and Tibet sections (Montenat et al., 1986; Girardeau et al., 1989) indicate the following main events:

- The Farah Rud Ocean opened in the late Paleozoic as suggested by the Turkman Valley and Rushan Pshart deposits (Karapetov et al., 1975; Ruzhentzev and Shvol’man, 1981). The Rushan Pshart zone, located between the Central and Southern Pamirs contains pelagic sedimentary deposits (shales, turbidites and radiolarites) of Late Permian age associated with basaltic submarine flows. These sedimentary and volcanic events may record the opening of the oceanic basin, for example, the presence of the Waras Ophiolite Complex.

The northern margin of the basin flanked the Band-e Bayan uplift and the western Hindu Kush. The character of the pre-Mesozoic continental basement beneath the Farah Rud Basin is not known, as no field data are available.

- A northward-dipping subduction zone was active during the Triassic as indicated by the plutonic calc-alkaline belt of the Hindu Kush-Badakshan regions (Figures 1, 30 and 31) and Rushan Pshart. Subsidence of the North Hindu Kush Basin and the accompanying intense calc-alkaline volcanic activity was the result of the same subduction process. Subduction ended in the Late Triassic or shortly thereafter and the basin began to close during the Jurassic as siliciclastic flysch deposits were deposited as a result of active erosion on the margin. In the Farah Rud Basin, flysch facies were deposited as late as the Neocomian.

- The Waras Ophiolitic Complex was obducted onto the southern continental block in Tibet and probably in Afghanistan. The metamorphic grade of the Waras volcano-sedimentary sequence increases to the south with abrupt changes in grade from gneisschist to amphibolite facies across major thrust faults. The closure was probably in response to the rapid extension phase of the Belouch oceanic basin.
• Deposition of shallow-marine deposits of Barremian-Albian age marked the end of these tectonic and metamorphic events and was followed by a late northward-directed back-thrusting event (see Figure 23) that was responsible for the main structures now observed prior to the deposition of Late Cretaceous limestone (Figures 6b and 31d).

Belouch Belts

The Belouch Belt was probably formed in the late Paleozoic (see above) but its pre-Triassic sedimentary history is unknown. The Altimour Triassic ‘ammonitico rosso’ facies indicates the presence of an oceanic margin or a possible seamount chain. The Kotagae and Rokian series indicate pelagic conditions. The Belouch Basin may have been in existence from the Triassic, but the age of the associated oceanic crust is debated since the related ophiolitic complexes are not accurately dated. The first indications of subduction of the Belouch Basin beneath the southeastern border of the Central Mountains are recorded in deposits of the uppermost Late Jurassic. The expansion of the basin must have begun in the Jurassic, or earlier still if the mafic volcanic deposits in the Middle-Up Triassic of the Kabul Block were controlled by extensional tectonics.

The paleogeographic evolution of the Belouch domain is complex and can be interpreted in various ways (see Figure 29). The Kotagae Series suite of basaltic and andesitic volcanics is not of oceanic origin and was probably formed in an island-arc environment associated with a marginal basin similar to the Kandahar Basin. Included sedimentary olistoliths suggest that the basin was located adjacent to the Kabul Block or Central Mountains.

In all the hypotheses, the Kabul Block appears as an isolated microcraton. The oceanic area (identified by the presence of the Logar Ophiolites) lying between the Central Mountains and the Kabul Block was probably relatively narrow and may have been a branch of the main ocean, represented in Afghanistan by the Belouch Basin. The main ophiolites of the Waziristan and Zhob ultramafic massifs were obducted in Pakistan onto the Indian Shield by the end of the Cretaceous prior to the deposition of Paleocene-Eocene sediments.

Magmatism Associated with Tethyan Subduction

The first intrusions of granite along the Central Mountains margin occurred at about 140 Ma; for example, the Ali Sha Granite (Blaise et al., 1972). Simultaneously, the Central Mountains Platform was disrupted by basement faults that resulted in alternating emerging ridges and subsiding basins. Subduction of the Tethyan oceanic crust under the Cimmerian landmass probably began in the Late Jurassic at about 145 Ma (Dercourt et al., 1993). The break in sedimentation during the Oxfordian recorded on the peri-Indian margin and in the Central Mountains is probably an aspect of the plate-tectonic evolution of the oceanic domain separating the two regions. This, however, has not been explained and may have been the result of a change in spreading rate, or inversion from expansion to resorption.

During the Early Cretaceous, active subduction beneath the Central Mountains is indicated by the following events:

• The existence of the Kandahar volcano-sedimentary basin consisting of a marginal basin and an active island arc (Figure 32).

• The emplacement along the entire southeastern margin of the Central Mountains (outcrop length about 450 km) of the Arghandab granodiorite axis (Figures 1 and 31). This is an Andean-type plutonic belt with emplacement ages of 70 to 110 Ma with the greatest frequency of intrusion at about 100 Ma. The magmatism and the manner of emplacement led Afzali et al. (1979) and Montenat et al. (1986) to conclude that subduction under the Central Mountains was accompanied by a component of lateral movement as a precursor of the Chaman shear fault. It should be noted that no Late Senonian or post-Cretaceous dates have been obtained for the granodioritic Arghandab axis of the Central Mountains margin.
Plutonic intrusions were not restricted to the Central Mountains. Calc-alkali granites in the south Pamirs and in Wakhan have geotectonic equivalents in the Central Mountains (see Figure 1). A Cretaceous (Aptian-Albian) island arc is present in Kohistan in Pakistan (Stöcklin, 1977; Bard et al. 1980) and farther to the east, the Cretaceous granodioritic axis of Laddakh is in an analogous position along the Tibetan margin with respect to the Indus-Tsang Po ophiolitic belt (Bassoullet et al., 1980). Large discontinuous Cretaceous granite plutons were also intruded close to the northern margin of the Central Mountain Block (see Figures 1 and 2) but granites are absent from the axial part of this block.

This axial zone corresponds to the Late Jurassic-Early Cretaceous Tirin flyschoid trough. The northern and southern shoulders of the trough, emergent, eroded or overlain by shallow-marine deposits, correspond to the areas where the plutons were later emplaced. During the mid-Cretaceous granitic intrusion event, the Central Mountains were emergent with the exception of the eastern margin and subjected to extensional faulting (Figure 33). The resultant grabens were filled with calc-alkali volcanics contemporaneous with granite intrusions at about 100 Ma and the whole Central Mountains Block was strongly deformed during the subduction process. In the Farah Rud Domain similar syn-orogenic grabens containing volcanics were formed following the metamorphism, folding and thrusting of the Waras and Panjaw series.

In post-Cretaceous times, a second, less well-defined granitic belt was intruded about 60 km to the southeast to form the Spin Boldak axis that can be traced into Pakistani Baluchistan. Radiometric dating indicates much younger ages at about 55 Ma (Paleocene-Early Eocene) (Wittekindt, 1973; Carbonnel et al., 1979) (Figure 1). This migration of calc-alkaline magmatism in time and space, perpendicular to the axis of the Central Mountains Block may be due to accretion resulting from the active Cretaceous subduction. It could have led to the displacement of the subduction zone toward the southeast at the beginning of the Tertiary.

During the Paleogene, the previously composite Cimmerian continent was disrupted by the collision with India (Treloar and Izatt, 1993). The central Afghanistan and eastern blocks of South Pamir and southern Tibet were displaced, resulting in major sinistral transcurrent movement on the Chaman Fault that was associated with dextral movement along the Herat Fault. The Paleogene Katawaz Flysch of eastern Afghanistan was deposited in the transcurrent zone adjacent to the Indian Plate (Dercourt et al.1993). Farther south in Afghanistan and Pakistani Baluchistan there were no converging continental blocks, only the precursor to the Indian Ocean, which today is being subducted south of Makran (inset Figure 1).

The effects of the Indian-Eurasian convergence were felt less intensely in Afghanistan than in those regions in the frontal collision zone of the Pamirs and Himalayas. Afghanistan is thus a key region for understanding the genesis and evolution of the Tethyan system. The day will come for geologists to return to work in the sublime landscape of the Afghan Mountains… a wealth of amazing discoveries awaits them!
Mesozoic of Afghanistan

(a) The Triassic carbonate platform sloped gently eastward into the Beloutch Basin (ammonitico rosso facies); basaltic eruptions on eastern margin.

(b) Early to Middle Jurassic: similar conditions as in (a), but the western margin was probably emergent and eroded.

(c) Regressive episode at the beginning of the Upper Jurassic (Oxfordian?).

Evolution of the median Tirin–Oruzgan Trough, closing northeastward and widening southwestward toward the Kandahar Basin. (d) Upper Jurassic; (e) Lower Cretaceous.

(f) Mid-Cretaceous emergence of the Central Mountains; development of graben filled with continental clastics and calc-alkali volcanics. Intrusions of granitoids along the shoulders of the earlier trough.

(g) In the Upper Cretaceous, the Central Mountains remained emergent.

Figure 33: Tectono-sedimentary and magmatic evolution of the Central Mountains during the Mesozoic.
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This work is dedicated to the memory of the late Professor Albert F. de Lapparent, an eminent pioneer of geological exploration in Afghanistan.

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