4. Faryab: Geology

4.1 Tectonic Overview

The geology of Afghanistan (Figure 4.11) is dominated by the Mesozoic (Cimmeride) and Tertiary (Himalayan - Alpine) orogenic episodes that have given the nation its mountainous core and which have controlled recent sedimentary deposition in the adjacent areas.

During the late Permian, a number of tectonic plate fragments (micro-plates) broke away from the southern “super-continent” of Gondwanaland (Figure 4.1). One of these, the Afghan micro-plate, collided with the Eurasian continental plate in the Mesozoic. This “Cimmeride” (also loosely referred to as “Hercynian”) orogenic episode commenced around the late Triassic and was complete by the Jurassic / Early Cretaceous (200-150 million years ago). The Cimmeride orogeny created the Paropamisus / Band-e Turkestan mountains, to the south of Faryab (Whitney 2006)

Around the Early Cretaceous, the Indian plate disengaged from Gondwanaland and subsequently collided with the Eurasian plate in the Palaeogene (late Palaeocene, early Eocene) resulting in further orogenesis, crustal thickening and crustal displacement (broadly referred to as the so-called Himalayan orogenic episode). South of the Harirud fault, the remnant of the Afghan micro-plate (the Afghan Block) has been (and is still being) squeezed south-westward at rates in excess of 1 cm/year by this crustal shortening (Whitney 2006).

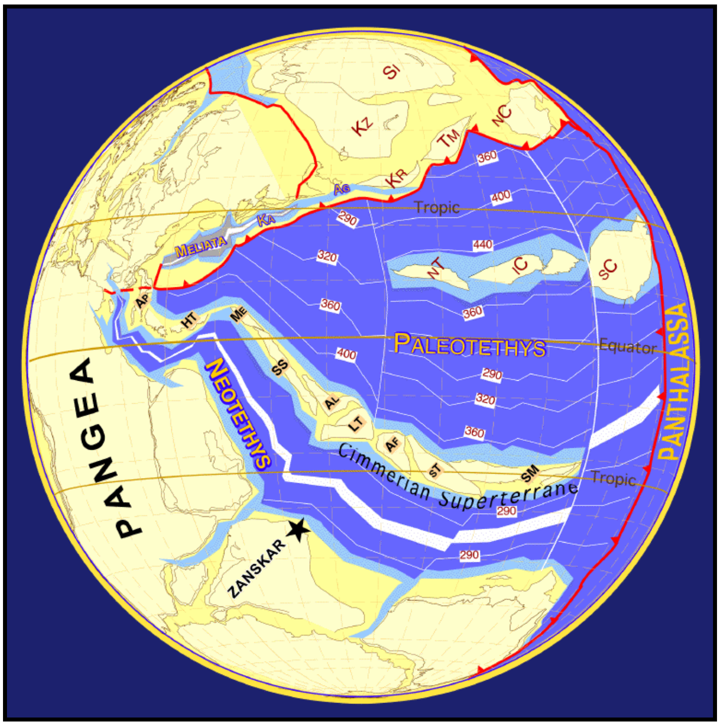

Figure 4.1. Plate tectonic reconstruction of the Himalayan region at 249 million years ago (late Permian / early Triassic). The Cimmerian superterrane, including the Afghanistan micro-plate (AF) is seen approaching Eurasia across the closing Palaeotethys Ocean. After Dèzes (1999); Available at http://en.wikipedia.org/wiki/Cimmerian_Orogeny.

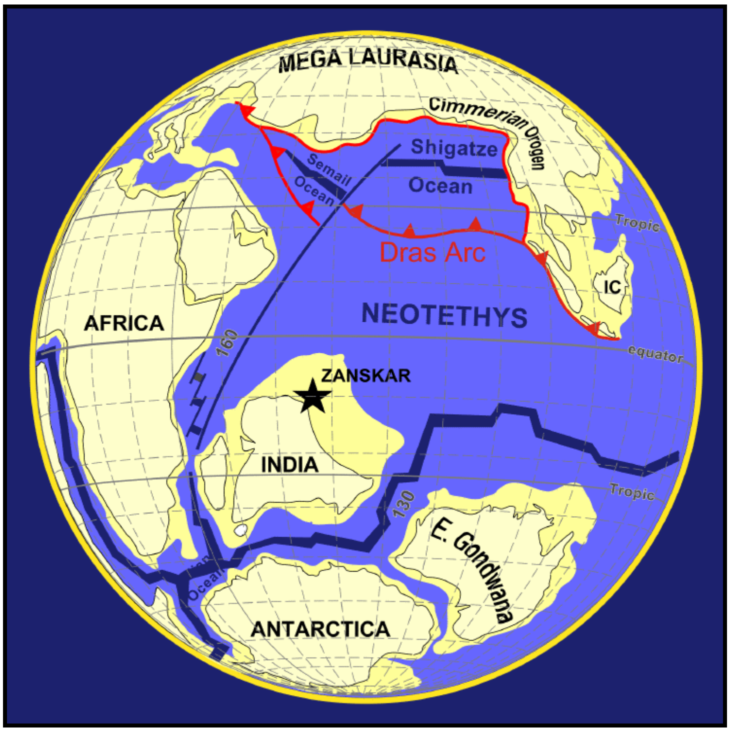

Figure 4.2. Plate tectonic reconstruction of the Himalayan region at 100 million years ago. The area of the Cimmeride orogen (now complete) is seen, as is the approaching Indian plate across the closing Neotethys Ocean. After Dèzes (1999); Available at http://en.wikipedia.org/wiki/Cimmerian_Orogeny.

The North Afghanistan Platform, on which Faryab is located, is thus an area of Cimmeride (pre-Jurassic) deformation. The Cretaceous and Palaeogene rocks are generally marine limestone and clastic sequences deposited in shallow basins. These were uplifted during the Alpine / Himalayan orogenic episode. The huge thicknesses of Neogene and Quaternary sediments in the northern part of Faryab are the erosional result of the most recent (Himalayan) episode of uplift and mountain-building.

4.2 The North Afghanistan Platform

Faryab sits upon the *North Afghanistan platform* - an area including and to the north of the Band-e Turkestan mountain chain. The platform thus represents the extreme southern edge of the former Eurasian plate.

Tectonic Structure

The Platform is typically divided into two distinct areas:

- the northern Murghab-Upper Amu Darya ***Basin***, which is the main, subsiding sedimentary basin accumulating Neogene and Quaternary deposits.
- the southern Paropamisus-Band-e Turkestan ***Uplift*** area

These two features seem to have acquired their tectonic character (subsidence and uplift, respectively) during and after the Himalayan-Alpine orogeny, although it is acknowledged as probable that they evolved as down-warped (“intracratonic rift sag basin” - Klett et al. 2006) or uplifted structures during Jurassic-Palaeogene times.

The Paropamisus-Band-e Turkestan Uplift area is subdivided into three distinct fault blocks, stepping down towards the north into the Murghab-Upper Amu Darya Basin. These are:

- The Qala-e Naw Fault Block

- The Maimana fault block and
- The Shebergan fault block.

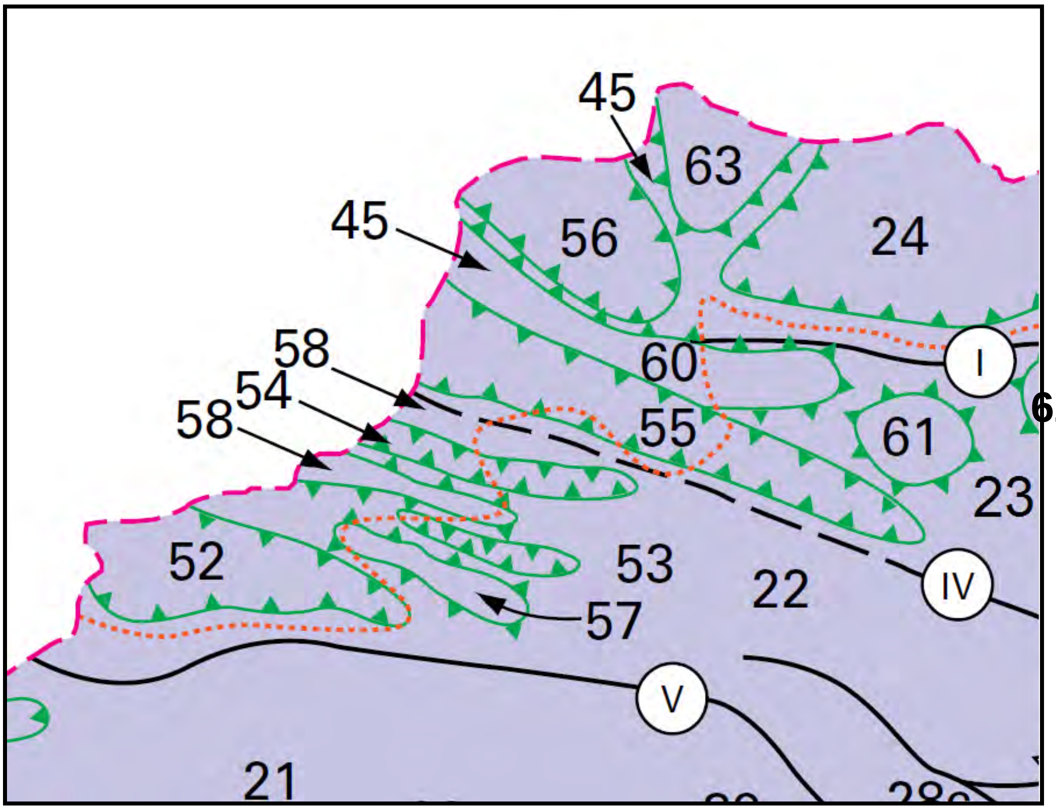

Figure 4.3. Tectonic map of the North Afghanistan Platform in the region of Faryab, after Abdullah & Chmyriov (2008), not believed to be copyrighted. The red dashed line shows the edges of the Murghab - Upper Amu-Darya Neogene-Quaternary basin. The green lines show areas of Alpine uplift or subsidence within the Cimmeride platform area.
<u>Paropamisus-Band-e Turkestan Uplift:</u> *21 - Qala-i Naw fault block; 22 - Maimana fault block; 23 - Shebergan fault block; 61 - Sheram arch; 62 - Shadian arch.*
<u>Afghanistan-South Turkmenistan Basin.</u> *24 - Surkhan (Mazar-e Sharif) megasyncline*. Troughs: *52 - Qala-i-Mor-Kaisar troughs, 53 - Almar trough, 54 - Ortepin trough, 55 - North Karabil - Dowlatabad trough, 56 - Obruchevskii trough.* Ramparts: *57 - Jekdalek, 58 - Khwaja Qol, 59 - Qara-Qol, 60 - Andkhoi, 63 - Pericline of South-West Gissar.*
<u>Neogene-Quaternary Basins:</u> *45 - Murghab - Upper Amu Darya*
<u>Major Faults:</u> *I - Alburz-Mormul; IV - Andarab-Mirza Wolang; V - Band-e Turkestan.* The *Band e-Turkestan Fault is approximately vertical and about 400 km long, separating the Qala-i Naw and Maimana fault blocks. It appears to be a right-lateral fault.*

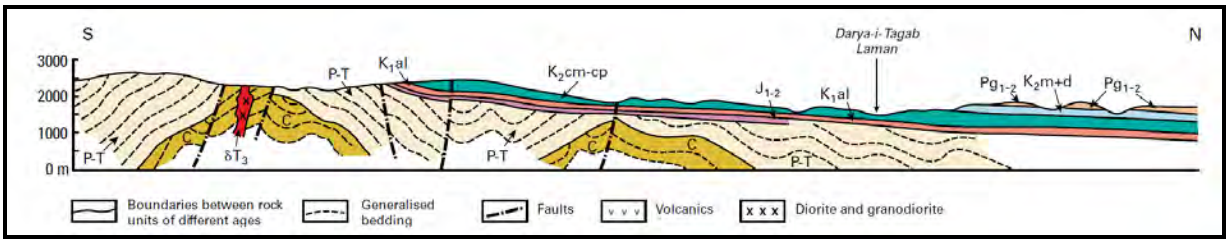

Figure 4.4. North-south cross section through the southern North Afghanistan Platform along the Darya-e Tagab Laman River, near Qala-e Naw, Badghis, after Abdullah & Chmyriov (2008a), not believed to be copyrighted. Note the relatively flat-lying Jurassic-Palaeogene sedimentary rocks sitting upon the folded Cimmeride basement.

Summary of Stratigraphy

According to Brookfield & Hashmat (2001), the stratigraphy of the North Afghanistan Platform can be roughly divided into three:

- Pre-Jurassic (pre-Cimmeride) folded basement of Palaeozoic to Triassic age.
- A post-Cimmeride, Jurassic to Palaeogene sequence of sedimentary rocks and some volcanic rocks, unconformably overlying the basement. These sedimentary rocks are relatively flat-lying, but show large scale flexure and deformation related to the Himalayan-Alpine orogeny.
- A syn- and post-Himalayan orogenic, Neogene to Quaternary continental clastic sequence.

The Jurassic-Palaeogene can be subdivided into four units:

1. A Late Triassic to Middle Jurassic rift succession, dominated by coarse, continental, coal-bearing clastics, laid down by braided and meandering streams in linear, rifting-related grabens.
2. Mid-Upper Jurassic mixed continental-marine clastic and carbonates, overlain by a regressive Upper Kimmeridgian–Tithonian evaporite-bearing sequence.
3. Lower Cretaceous red-beds and evaporites (unconformably overlying the Jurassic), succeeded by a transgressive sequence of Cenomanian to Maastrichtian shallow marine limestones.
4. Palaeocene to Eocene marine limestones with gypsum, succeeded by thin conglomerates and brackish-marine Upper Oligocene / Lower Miocene shales.

Information Sources

The most recent geological maps of Faryab are those at 1:250,000 scale, provided by the Afghan Geological Survey, assisted by the U.S. Geological Survey, although these are largely based on the mapping of earlier Afghan and Soviet geologists. The sheets covering Faryab are published by:

- McKinney & Sawyer (2005), covering the southern part of Faryab: Maimana, the Band-e Turkestan, Kohistan, Almar, Qaysar and Gurziwan.
- McKinney & Lidke (2005), covering the extreme east of the study area, including Ghormach.
- Wahl (2005), covering the northern part of Faryab, including Shirin Tagab, Dowlatabad and Andkhoi.

The British Geological Survey has also re-published the two volumes of the Geology of Afghanistan by Abdullah & Chmyriov (2008a,b). Originally written in Russian and published by Nedra in Moscow, the volumes reflect the Soviet unwillingness to fully embrace modern plate tectonic theory, but nevertheless remain an extremely comprehensive and systematic source work.

The following is largely derived from the sources mentioned above and (especially) Dronov's (2008b) overview.

4.3 Pre-Cimmerian Rocks in Faryab and the North Afghanistan Platform

At depth, the North Afghanistan Platform comprises a folded Palaeozoic-Triassic basement that was intruded by granites (not exposed in Faryab) during the last stages of the subduction of the Palaeotethys Ocean (BGS 2014). In Faryab, the Cimmerian

basement is most prominently exposed in the fault-bounded, horst-like Band-e Turkestan mountain range. The units mapped in Faryab include:

C_2ls Late Carboniferous: dominated by limestones, with subordinate clastic sedimentary rocks (slates, sandstones, conglomerates, siltstones) and volcanic rocks (andesites, basalts).

Pssl Permian: dominated by red and variegated sandstones and siltstones, with subordinate conglomerates and mudstones.

T_1ssc Early Triassic: dominated by variegated marine sandstones and conglomerates, with subordinate chert and volcanic rocks (rhyolite, basalt).

T_{23}ssl Middle-Late Triassic sedimentary complex: dominated by marine sandstones and siltstones, with subordinate carbonaceous shales, mudstones, limestones, marls conglomerates, acidic and mafic volcanics. The late Triassic terrigenous deposits have been described as flysch.

4.4 Jurassic-Palaeogene Rocks in Faryab and the North Afghanistan Platform

The Cimmeride orogeny was largely complete in the Faryab area by the Jurassic. Following the orogeny, the mountain chain was eroded and peneplained. The northern part of the North Afghanistan Platform thus started subsiding and accumulating sediments.

Jurassic

Early to Middle Jurassic: Initially, erosion of the Cimmeride mountain chain produced a sequence of Jurassic clastic sediments on the new Cimmeride basement. The early-mid Jurassic clastic sequence contains some coal lenses and layers and is known to reach 100-1450 m in thickness, known as the **Sayghan Series.**

Middle to Upper Jurassic: Towards the end of the Middle Jurassic (167 Ma BP), conditions changed in the northern part of the platform, with marine carbonate sequences becoming predominant (Bathonian - Oxfordian). The carbonates are an important hydrocarbon reservoir rock and are referred to as the **Kugitang** or **Gissar Formation.**

Upper Jurassic: In the Upper Jurassic (Kimmeridgian-Tithonian), terrigenous red-bed (conglomerate, sandstone, siltstone) and evaporites again became predominant. One especially thick evaporite sequence forms the cap rock for the Middle-Upper Jurassic hydrocarbon reservoirs and is referred to as the **Gaurdak Salt Formation** (includes anhydrite, halite and some sylvite, Ulmishek 2004)**.** The Gaurdak salt generally increases in thickness to the north and pinches out to the south of Andkhoi (Figure 4.7).

The Jurassic strata are not exposed to any extent in Faryab, but are known at depth from drilled boreholes and are known to produce significant quantities of geothermal groundwater.

Cretaceous

Late Jurassic terrigenous clastic deposition continued into the Cretaceous.

K_1ssc Early Cretaceous: In Faryab, the early Cretaceous is represented largely by red sandstones and conglomerates, with less abundant siltstones, gypsum evaporites and clays. Near the Paropamisus-Band-e Turkestan Uplift in the south, the deposits are coarser-grained and of a terrestrial nature. To the north, in the Murghab-Upper Amu Darya Depression, the sediments are finer, with some marine layers and lenses within the terrigenous sequence. The deposits can reach 1000 m in thickness.

The Hauterivian (Lower Cretaceous) sandstones of the Qezeltash Formation are an important hydrocarbon reservoir rock. Figure 4.5 shows structural contours on the top of the Qezeltash sandstone formation in Faryab.

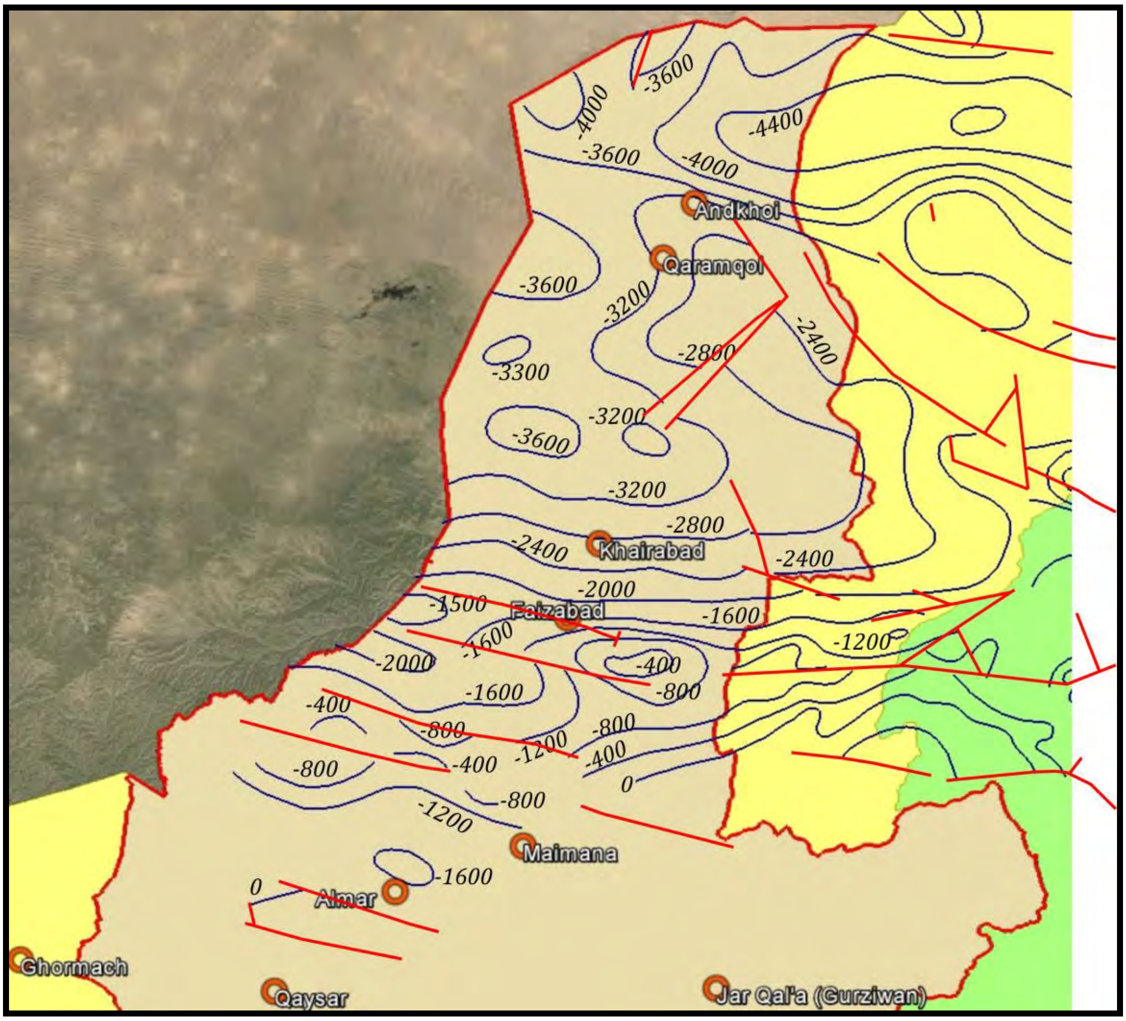

Figure 4.5. Structure contours on the top of the Hauterivian (early Cretaceous) Qezeltash sandstone formation in m relative to sea level in Faryab. Based on data of Steinshouer et al. (2006). See also http://pubs.usgs.gov/of/2006/1179/metadata/qezeldpafg.htm. Red lines show faults transposed from Ghory Formation map of Klett et al. (2006).

Towards the end of the Early Cretaceous, marine conditions started transgressing from the north-north-west, with a finer grained, mainly clastic sequence accumulating in shallow marine basins, with the sediment supply coming from the Paropamisus-Band-e Turkestan Uplift.

K_2ssl Late Cretaceous clastic facies: In Faryab, the late Cretaceous is represented largely by shallow marine sandstones and siltstones, with less abundant clays, limestones, marls, conglomerates and gypsum evaporites.

From the start of the Cenomanian (start of the Late Cretaceous) onwards, marine carbonate facies start appearing, especially in the north and south-east of the area. By the end of the Cretaceous (Campanian-Maastrichtian), the marine transgression of the North Afghanistan Platform is almost complete, and marine platform deposits of limestone/dolomite sediments predominate. This deposition continued until the Palaeogene. The Maastrichtian-Palaeocene in the southern (Paropamisus-Band-e Turkestan) part of the platform is dominated by a carbonate reef facies, which can reach

up to 777 m thick. In the north, in the Murghab-Upper Amu Darya Depression, the deposits are more terrigenous in nature, with no reef facies and up to 600 m thick.

KP_1ld Late Cretaceous and Palaeocene carbonate facies (often referred to as the Ghory Formation): Deposits of marine limestones, marls and dolomites, with less abundant sandstones, clays, siltstones, gypsum, and conglomerates. The Ghory formation is some 150-170 m thick on the Maimana Step (Klett et al. 2006).

The Ghory Formation is a hydrocarbon reservoir rock in some areas, capped by Eocene mudstones. Figure 4.6 shows structural contours on the top of the Upper Campanian to Palaeocene Ghory formation in Faryab.

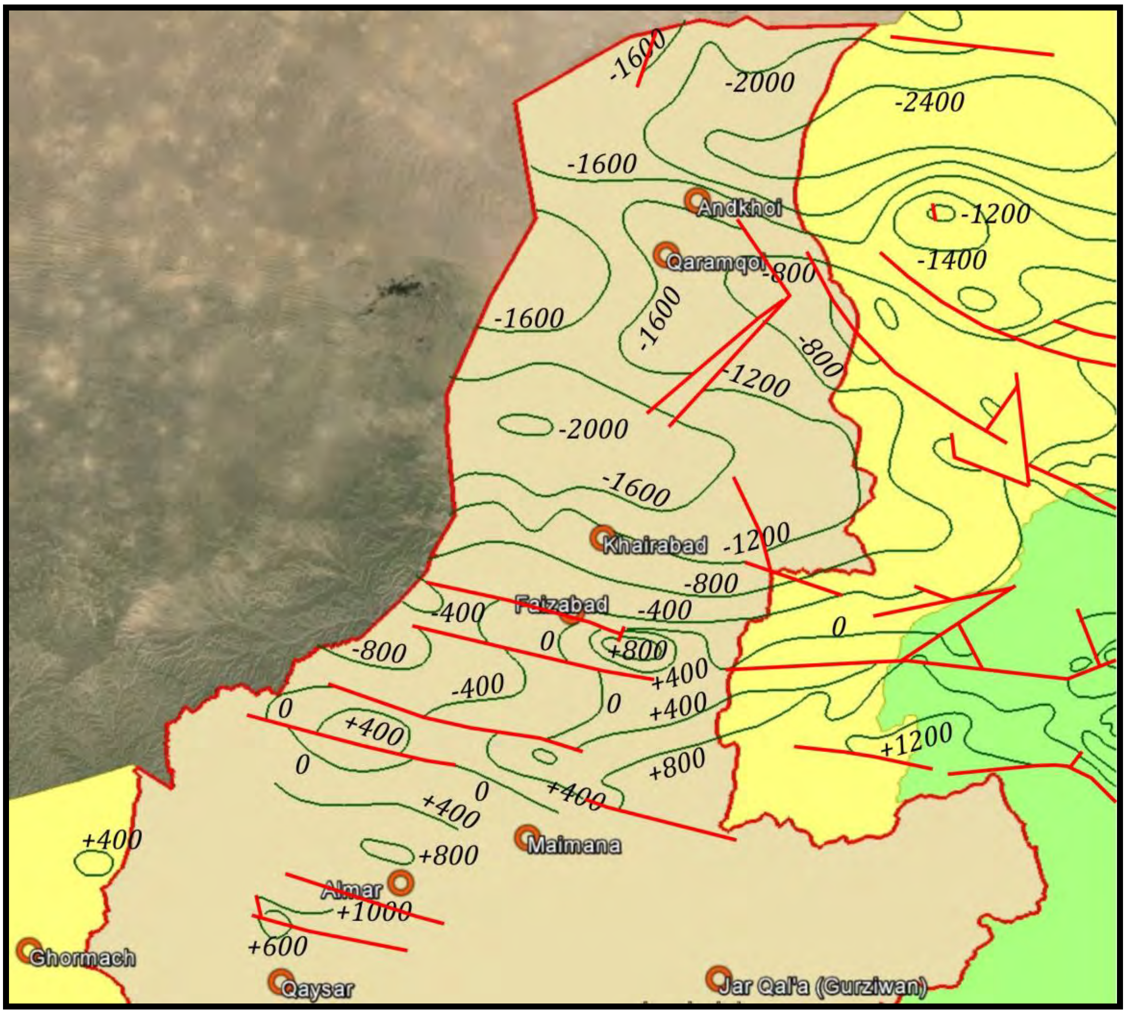

Figure 4.6. Structure contours on the top of the Campanian-Palaeocene Ghory carbonate formation in m relative to sea level in Faryab. Based Steinshouer et al. (2006). See also http://pubs.usgs.gov/of/2006/1179/metadata/ghorydpafg.htm. Red lines show faults (after Klett et al. 2006).

Palaeogene

KP_1ld Late Cretaceous and Palaeocene: see above.

During the Eocene, sedimentation was more dominated by terrigenous, fine clastic material, up to 800 m thick, in a marine basin.

P_2csh Eocene: In Faryab, Eocene deposits of clay, shale and siltstone are observed, with less abundant sandstone, limestone, marl, gypsum and conglomerate.

In the Eocene and Oligocene, some volcanic deposits are recorded from the North Afghanistan Platform, although these are not specifically mapped in Faryab.

4.5 Neogene and Quaternary Rocks in Faryab and the North Afghanistan Platform

The final stages of subduction of the Neotethys Ocean, as the Indian plate converged on the Afghan plate, took place in the Cretaceous and Tertiary, with volcanic activity further south and some intrusion of Oligocene/Miocene granites as far north as north-eastern Afghanistan. The Himalayan - Alpine orogenesis culminated in the late Palaeogene / early Neogene.

The focus of the Himalayan - Alpine orogeny was further south in Afghanistan than Faryab: nevertheless, the effects were felt in the North Afghanistan Platform area as an uplift of the southern part of the platform, commencing towards the end of the Eocene. Thus, Oligocene deposits are essentially absent in outcrop. Some Eocene-Oligocene shallow and partly fresh water sediments were deposited in the northern Murghab-Upper Amu Darya Depression.

The Uplift was coupled with dramatic erosion and deposition of Neogene and Quaternary proluvial and alluvial sediments in sedimentary basins to in the northern part of the North Afghanistan Platform, collectively referred to as the Afghanistan-South Turkmenistan Basin (or, in Faryab, as the Murghab-Upper Amu Darya basin).

Neogene

At the culmination of the Himalayan-Alpine orogeny, the Murghab-Upper Amu Darya Depression started subsiding very rapidly relative to the uplifted Paropamisus-Band-e Turkestan area and thus started accumulating vast thicknesses (up to 14,000 m) of predominantly terrigenous sediments. The upper Oligocene to Quaternary succession is probably no greater than 1.5 km thick, however, in the Murghab depression (Figure 4.7) and adjacent areas (Ulmishek 2004, Klett et al. 2006). Within the southern uplifted area, minor, local sedimentary basin structures also developed (see Figure 4.3). The deposits commenced with finer material and coarsened as uplift continued. Adjacent to the main uplifted mountain areas, one might describe these deposits as “molasse”-type proluvial deposits, “dumped” in huge poorly-sorted alluvial fan structures washing out of the uplifted mountain areas.

The main stratal divisions mapped at outcrop in the AGS/USGS maps are:

N_1dig Miocene: in eastern Kohistan, a few small igneous intrusions of diorites, granodiorites and associated igneous rocks are noted.

N_{1l}csl Early Miocene: Predominant red clays and siltstones, with less abundant sandstones, conglomerates and limestones.

N_{1m}csl Middle Miocene: Predominant brown clay and siltstone, with less abundant sandstones, conglomerates and limestones.

Note that the AGS/USGS maps show the outcropping Neogene deposits in Faryab as Miocene, while the description of Abdullah & Chmyriov (2008a) implies that the Quaternary further north may be underlain by a thick Pliocene sequence, overlying the Miocene.

The AGS/USGS maps suggest that the outcropping Neogene deposits of Faryab are predominantly fine grained siltstones and clays. This is likely because the mapped outcrops represent only the **Lower Miocene Shafay Formation** and **Middle Miocene Kashtangi Formation**, both of which are dominated by red-brown finer grained clastics.

Other sources (Table 4.2 and Dronov & Chmyriov 2008) suggest that in large portions of the Neogene sequence, coarser sandstones and conglomerates may predominate. For example, in the **Upper Miocene Rustak Formation**, the **Lower Pliocene Kokcha Formation** and the **Upper Pliocene Keshm Formation**, coarser grained sandstones and conglomerates are more dominant (Dronov 2008a).

The lower Neogene sediments typically contain gypsiferous clays and siltstones and it is anecdotally reported that halite also occurs.

Quaternary

During the Quaternary, the northern Murghab-Upper Amu Darya Depression continued subsiding rapidly relative to the uplifted Paropamisus-Band-e Turkestan area, and alluvial sedimentation continued. As the tectonic situation began to stabilise intermittently, discrete "terrace" levels of alluvial sedimentation could be identified. The thickness of Quaternary sediments can reach several km in the deepest basins of the North Afghanistan Platform.

Q_1a Early Pleistocene alluvium: Predominantly gravels and sands (sometimes lithified), with silts and clays.

Q_2a Middle Pleistocene alluvium: Predominantly gravels and sands (sometimes lithified), with silts and clays. Occurs at high elevations in south of Faryab as a cover deposit overlying Cretaceous / Palaeogene and Neogene deposits. Some GIS data sets map this as late Pleistocene / Holocene Q_{34}t glacial till.

Q_2loe Middle Pleistocene loess: loess (silt) with some sand and clay. Wind-blown loess results from aeolian erosion of the vast alluvial plains during periglacial episodes of the Pleistocene. From published geological maps we must deduce that these loess deposits can reach several tens of metres thickness.

Q_3a Late Pleistocene alluvium: Predominantly gravels and sands (sometimes lithified), with silts and clays.

Q_{34}e Late Pleistocene / Holocene aeolian sands: Occurs as cover deposits over alluvial plains in the semi-desert area in the north of the region.

Q_{34}a Late Pleistocene / Holocene alluvium: Predominantly gravels and sands (sometimes lithified), with silts and clays. Occurs mainly along modern river channels.

Q_4sm Recent Quaternary salt marsh deposits: Mud, silt, and clay, with some sand, limestone, gypsum and salt. The main salt basins (intermittent saline lakes) in Faryab are the **Khwaja Mod** (gypsum and halite), c. 20 km NNE of Khairabad, and the **Chakan** on the eastern border of Dowlatabad district. As of 1995, halite was being mined for table salt from the Khwaja Mod deposit on a small scale (Orris & Bliss 2002). The northern semi-desert area and the Karakum of Turkmenistan also contain takyrs or solonchaks.

The entire Neogene / Quaternary sequence of the northern Faryab plains and the Karakum of Turkmenistan can be regarded as the ancient proluvial / alluvial / lacustrine deposits of the precursors to the Shirin Tagab, Murghab and palaeo-Amu Darya rivers (see Chapter 3.9 and Fyedorovich 1979). The map of Krizhanovskii (1972) indicates the thickness of the Quaternary in the Turkmen desert, above the Neogene, as shown in Table 4.1.

Table 4.1. Depth to base of Quaternary in selected Soviet exploration boreholes in the Turkmen desert near Faryab, from Krizhanovskii (1972), see Figure 8.1 for locations.

Soviet borehole number	Estimated ground level (m asl)	Depth of borehole (m)	Depth to base of Quaternary (m)
182	251	82.7	Neogene not recorded
183	275	100.8	Neogene not recorded
188	722	301.4	170.0
189	519	252.3	Neogene not recorded
190	359	135.8	108.9
194	835	600.0	30.8
195	620	50.0	7.05

Table 4.2. Summary stratigraphic table of the sedimentary sequences on the North Afghanistan Platform. Modified after Annex 15 of Abdullah & Chmyriov (2008a). Not believed to be subject to copyright.

Tectonic Cycle	Structural Formation Complex	QALA-I-NAW FAULT BLOCK AND WEST MAYMANA FAULT BLOCK	SHEBERGHAN FAULT BLOCK	AFGHANISTAN - SOUTH TADJIKISTAN DEPRESSION
		Formations	Formations	
		Sedimentary and sedimentary-volcanogenic rocks	Sedimentary and sedimentary-volcanogenic rocks	Sedimentary and sedimentary-volcanogenic rocks
Orogenic	Quaternary	Q Grey, terrigenous, terrestrial	Q Grey, terrigenous, terrestrial	Q Grey, terrigenous, terrestrial
Orogenic	Pliocene	N_2 Variegated to grey, terrigenous, terrestrial 50 - 250m	N_2?	N_2 Variegated to grey, terrigenous, terrestrial 9,000m
Orogenic	Miocene	N_1 Variegated to red, terrigenous, terrestrial 300 - 800m	N_1 Variegated to red, terrigenous, terrestrial 1,100 - 1,550m	N_1 Variegated to red, terrigenous, terrestrial 1,100 - 5,750m
Orogenic	Eocene - Oligocene	Pg_{2-3} Terrestrial volcanogenic (porphyry) 250 - 1,400m	Pg_{2-3} ?	Pg_{2-3} ?
Cratonic	Jurassic - Eocene	Pg_2 Terrigenous 250 - 700m	Pg_2 Terrigenous 400m	Pg_2 Terrigenous 400 - 620m
Cratonic	Jurassic - Eocene	K_2m-Pg_1 Carbonate 150 - 1,150m	K_2m-Pg_1 Carbonate 200 - 600m	K_2 Terrigenous-carbonate 150 - 1,700m
Cratonic	Jurassic - Eocene	K_2 Carbonate-terrigenous 250 - 500m	K_2 Carbonate-terrigenous 300 - 1,700m	
Cratonic	Jurassic - Eocene	K_1 Carbonate-terrigenous 90 - 130m	K_1 Green to variegated (marine in the upper portion, terrestrial in the lower portion) 550 - 850m	K_1 Carbonate-terrigenous (marine in the upper portion, terrestrial in the lower portion) 170 - 850m
Cratonic	Jurassic - Eocene	J_3 Terrigenous 800m	J_3 Terrigenous-carbonate and evaporite 700 - 1,150m	J_3 Terrigenous-carbonate and evaporite 250 - 1,150m
Cratonic	Jurassic - Eocene	J_{1-2} Terrigenous (coal-bearing) 60 - 100m	J_{1-2}?	J_{1-2} Terrigenous (coal-bearing) 1,250 - 1,450m
In superimposed troughs	Triassic	T_3r ?	T_3r ?	T_3r Terrigenous, terrestrial 350m
In superimposed troughs	Triassic	T_{2-3} Dark-coloured, terrigenous, marine 2,200 - 4,000m	T_{2-3} Dark-coloured, terrigenous, marine 1,100m	T_{2-3}?
In superimposed troughs	Triassic	T_1 Variegated volcanogenic-terrigenous, marine 150 - 2,000m	T_1 ?	T_1 ?

4.6 Oil and Gas deposits of the North Afghanistan Platform

Oil and gas resources are located in the huge Mesozoic-Tertiary sedimentary basin of northern Afghanistan, which can broadly be subdivided (Klett et al. 2006) into an eastern **Afghan-Tajik Basin** and a western **Murghab-Amu Darya basin**, separated by the **Gissar Mega-anticline** (Figure 4.7). According to Brookfield & Hashmat (2001), the oil and gas traps of the North Afghanistan platform are mainly associated with:

- Upper Jurassic carbonates, sealed by cap rocks of Upper Jurassic evaporite salt (Gaurdak salt formation). The Gaurdak salt generally increases in thickness to the north and pinches out to the south of Andkhoi (Figure 4.7). These evaporites occur at depths of c. 3 to 3.6 km in the North Karabil-Dowlatabad trough and at 4 to 5 km in the Obruchev trough (Klett et al. 2006).
- Lower Cretaceous sandstones, sealed by Aptian–Albian shales and siltstones.
- To a lesser extent, Upper Cretaceous / Palaeocene carbonates, sealed by cap rocks of Palaeogene shales.

The structural traps are typically anticlinal structures related to Neogene wrench faulting, and the hydrocarbon sources are mainly in the Jurassic (mostly the Lower-Middle Jurassic coal-bearing strata).

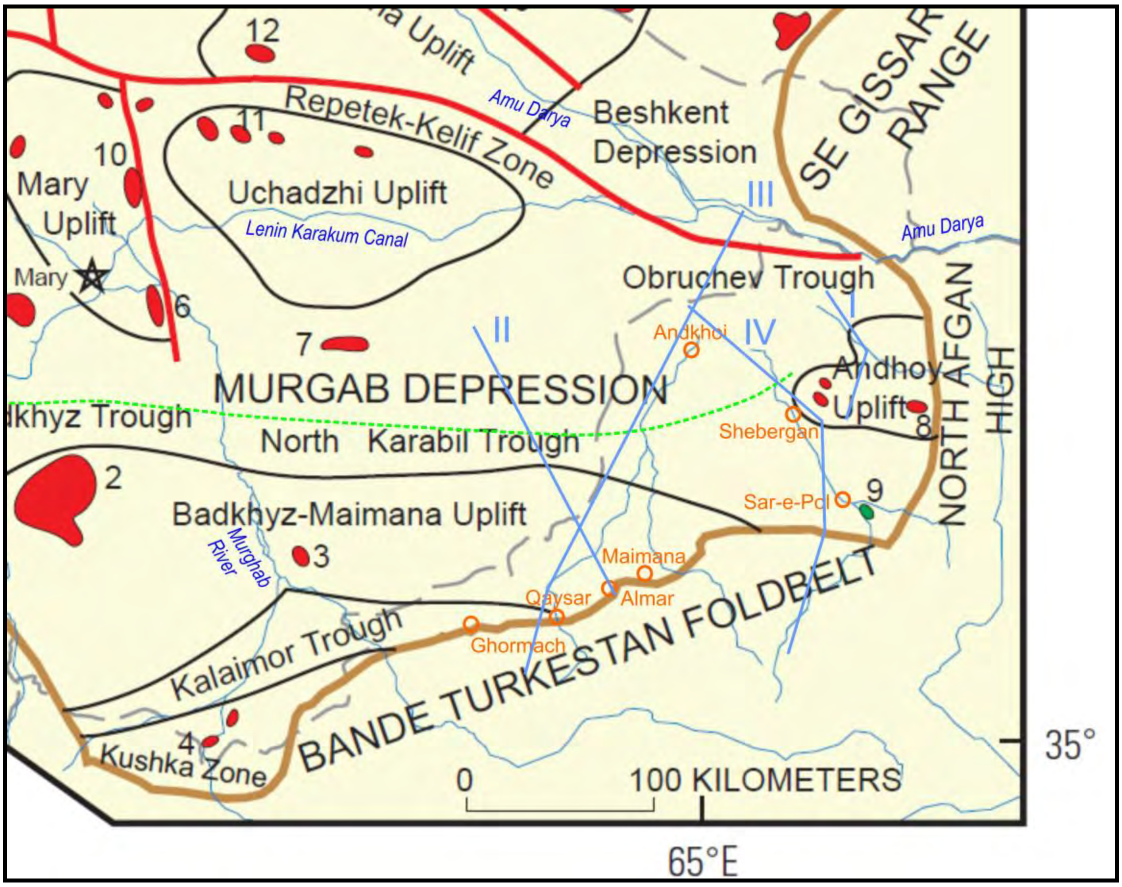

Figure 4.7. Structural map of northern Afghanistan and the Amu Darya basin, showing gas (red) and oil (green) reserves. The boundary of the Murghab-Amu Darya basin is shown as a thick brown line (note that many of the main towns of Faryab - orange circles - lie on the transition from the Band-e Turkestan uplift to the Murghab-Amu Darya depression). 8 = Hodja Gugerdag gas fields, 9 = Angot oil field. The dashed green line shows the pinch-out to the south of the Jurassic Gaurdak Salt Formation. The blueish lines marked I, II, III and IV show the approximate positions of Figures 4.8-4.10. After Ulmishek (2004), and ultimately presumed to be partly based on Bratash et al. (1970). *Not believed to be subject to copyright (public domain USGS report).*

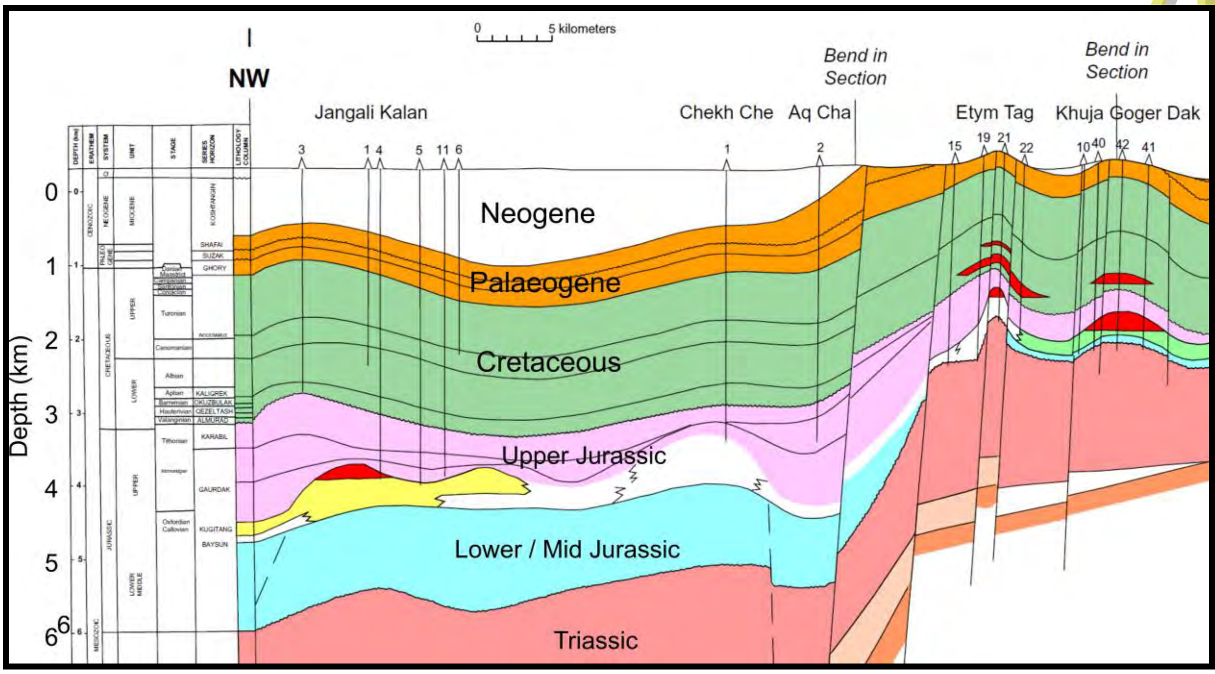

Figure 4.8. Cross-section over the Andkhoi uplift in Jawzjan Province from NW (left) to south (right). Approximate line of cross-section shown as I on Figure 4.7. Modified after Klett et al. (2006). Gas deposits are shown in red. USGS Public domain report, not believed to be subject to copyright.

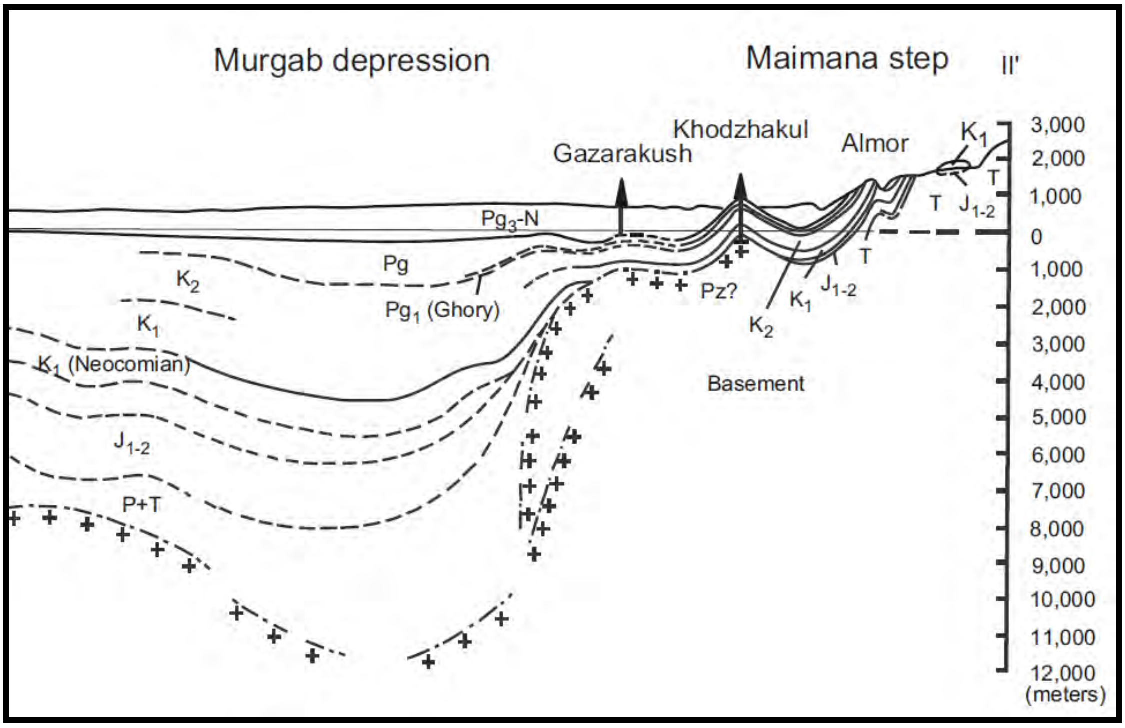

Figure 4.9. Cross-section north-west from Almar (south-east, right) into Turkmenistan (north-west, left). Approximate line of cross-section shown as II on Figure 4.7. After Klett et al. (2006). USGS Public domain report, not believed to be subject to copyright.

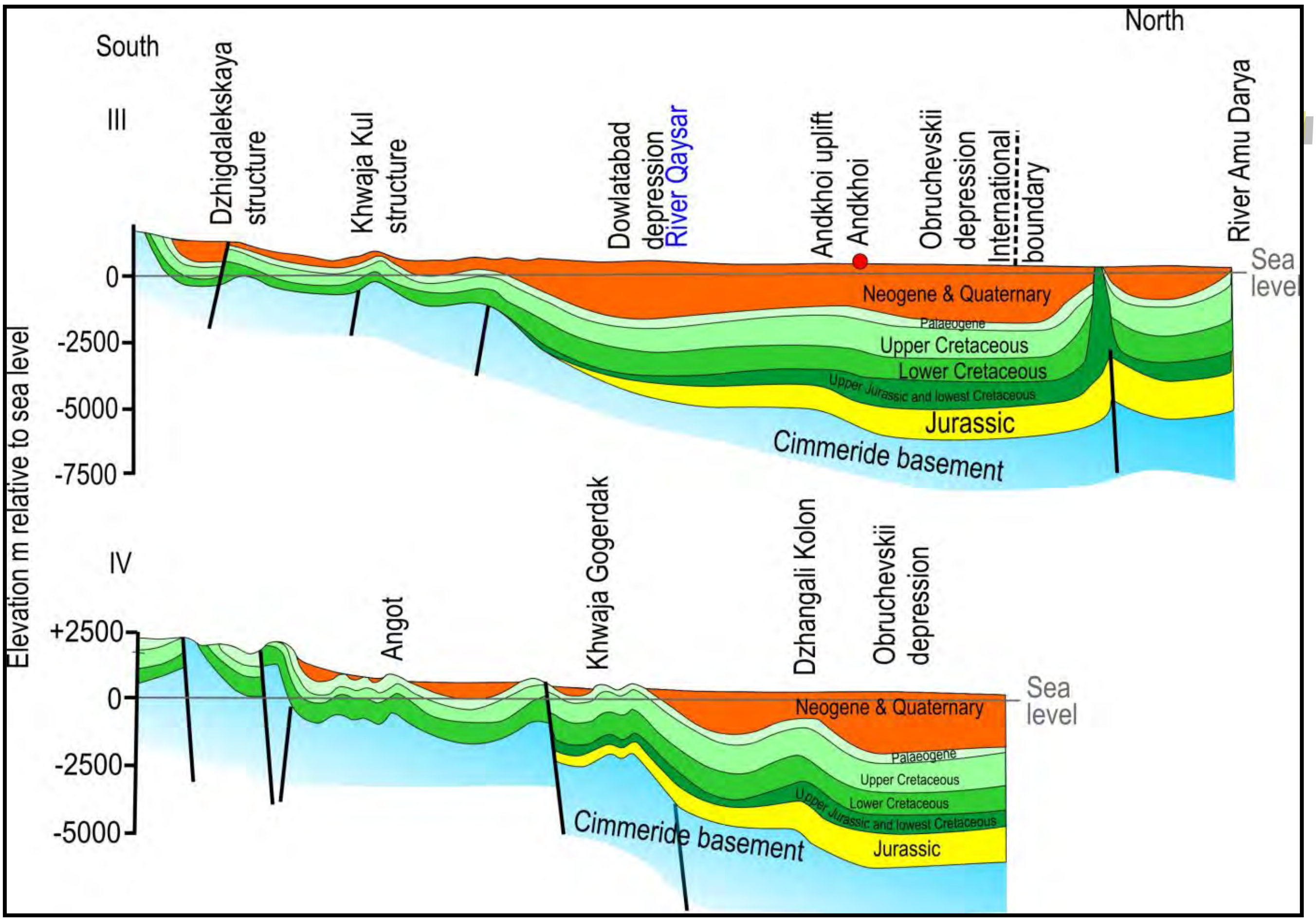

Figure 4.10. (top) Cross-section NNE from the mountains south of Qaysar, through Andkhoi to the Amu Darya. Approximate line of cross-section shown as III on Figure 4.7. **(bottom) Cross-section from the mountains, north through the vicinity of Sar-e Pol and Shebergan to near Andkhoi.** Approximate line of cross-section shown as IV on Figure 4.7. Based on documents by Bratash et al. (1970).

Of Etymological Interest

The name **Band-e Turkestan** means *Boundary wall of Turkestan*. It is the main mountain range of southern Faryab and runs in a west-east direction for 200 km. According to Iranica Online (2014), the summit level (3,200-3,300 m; highest point 3,481 m) probably represents a pre-Miocene erosional, peneplained surface, which was subsequently uplifted during the Himalayan-Alpine orogeny.

The **Paropamisus** refers to the western part of the Hindu Kush range in Afghanistan (including the Siah Koh, Safed Koh, Chalap Dalan, and Malmand ranges). One possible derivation of the name is that it is from the Sanskrit "Para-Vami" - *the excellent and pure city of Vami (Bamyan).*

Firoz Koh. The Siah Koh and Safed Koh are the southern and northern branches of the Firoz Koh range, respectively. **Safed Koh** means *White Mountain* and **Siah Koh**, *Black Mountain.* The Safed Koh range of western Afghanistan is distinct from the Safed Koh range of southeastern Afghanistan (McKerrow 2008).

Flysch - marine clastic sediments, typically deposited as turbidites in a foreland basin of an incipient continental collision. These are often deformed during orogenesis by thrusting.

Molasse - typically coarser sands, conglomerates and shales eroded from a rapidly-rising mountain chain and deposited in the foreland basin. The molasse deposits thus succeed, and may be deposited on top of, flysch. Molasse is typically terrestrial proluvial, alluvial and occasionally lacustrine or shallow marine in nature.

Proluvium - a Soviet geological term used to describe alluvial fan deposits forming as outwash from mountain massifs. "*Proluvium forms alluvial fans and, where they merge, proluvial trains. The texture of the detrital material changes from pebbles and gravel with fanglomerates at the top of the fan to finer, more highly sorted sediments, frequently loess-like loams and sandy loams (proluvial loesses), at the bottom. Proluvium is most fully developed in the foothills of arid and semiarid regions where aleurite-clay sediments (frequently gypsumized and salinized) from flash floods sometimes form on the periphery of the area of proluvium distribution*". The Great Soviet Encyclopaedia (1978).

Aleurite - a term often used in Soviet / Russian geological texts to denote a silt-grade unconsolidated clastic deposit. An **aleurolite** is the equivalent consolidated deposit (a siltstone).

Takyr - is a shallow depression in a semi-desert area, with a clayey base, that fills with water when it rains. As the accumulated water evaporates, the clayey surface desiccates and fractured crust is formed, often containing filamentous cyanobacteria. Salinisation may develop at or below the surface, typically of gypsum and halite, as accumulated salts are leached out of the soil and concentrated. A saline takyr is often referred to as a **solonchak** (Berg 1950).

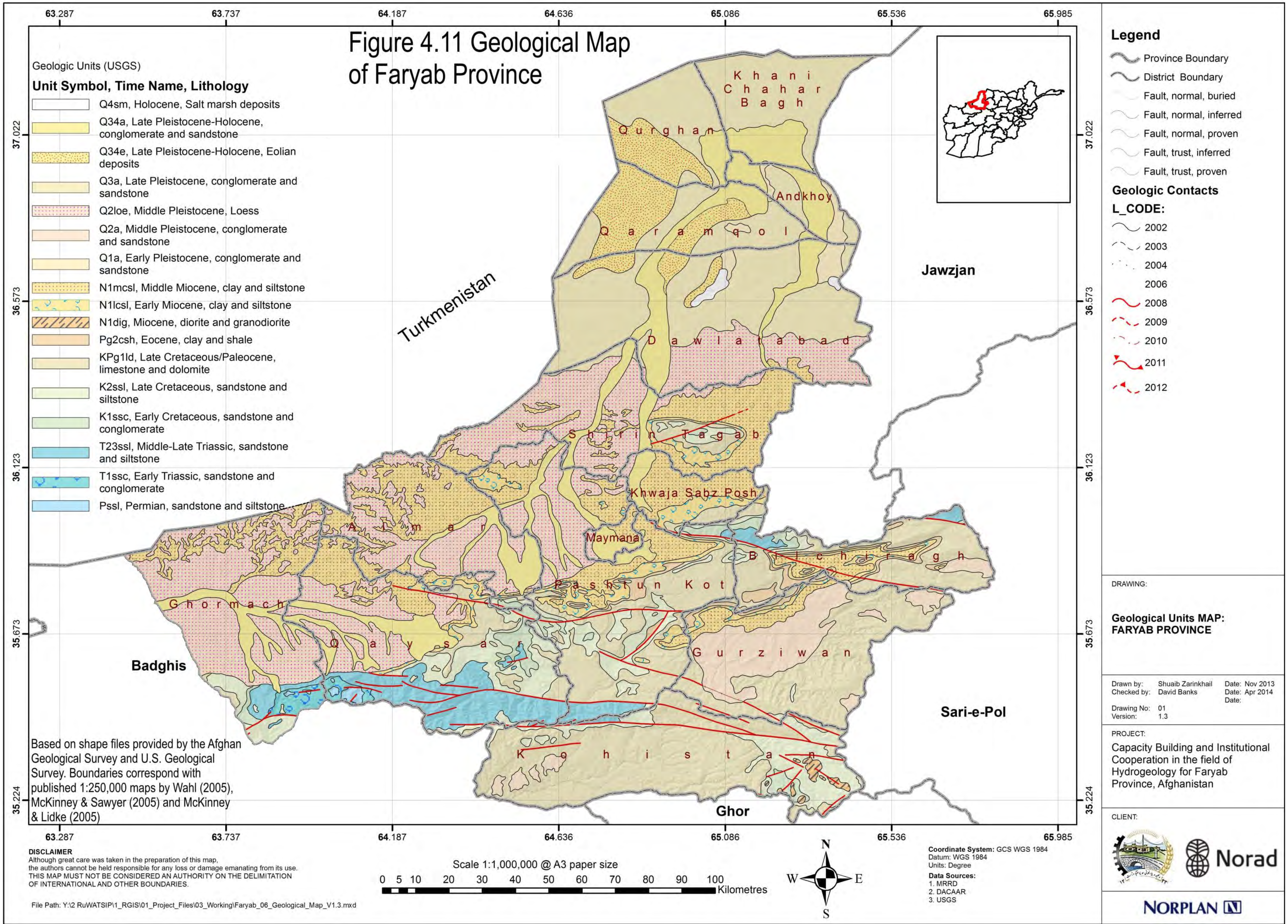

Figure 4.11 Geological Map of Faryab Province