Chapter 9
Pakistan

Uranium deposits and noteworthy occurrences are reported from the Dera Ghazi Khan District, Sulaiman Range, the Bannu Basin, and Issa Khel, Mianwali District, in central Pakistan, and from the Kirthar Range in south Pakistan (Fig. 9.1). Known deposits are of sandstone type, small in size, and of high cost uranium.

Pakistan’s former U production was essentially concentrated in the Dera Ghazi Khan District; OECD-NEA/IAEA (2005) estimates a cumulative production of 970 t U from 1971 through 2004, and an annual production on the order of 40 t U in the early 2000s. Mining was by conventional and ISL techniques. The "Baghal Chur-I" (BC-I) mill at Dera Ghazi Khan served the Dera Ghazi Khan District. It started up in 1971 as a pilot plant. Issa Khel was mined by open pit and underground methods and the ore processed by heap leaching. In recent years, ISL operations in the Bannu Basin may also have provided some production.

A number of radioactive localities associated with alkaline igneous rocks, pegmatites, and schists have been discovered in the mountainous northern part of Pakistan.

All uranium exploration is in the responsibility of the state-owned Atomic Energy Minerals Centre (AEMC) based in Lahore. The following description is based on Baig (1990), Moghal (1974a,b), OECD-NEA/IAEA/IUREP (1978), OECD-NEA/IAEA (1997, 1999) amended by data from other authors cited in the sections of the various uranium districts.

Historical Review

First reports on the discovery of uranium mineralization date back to the year 1959. U was found in Siwalik sandstone near Rakhi Munh in the Sulaiman Range. Subsequent exploration led to the discovery of about a dozen small U deposits in the Dera Ghazi Khan District in the early 1970s. Taunsa, discovered in 2000/2001 in this district, was the latest success.

Exploration in other parts of Pakistan resulted in numerous U showings in Siwalik sediments and crystalline rocks but no deposits, except for the small Qubul Khel deposit in the Bannu Basin and Kallar Kahar in the Salt Range (OECD-NEA/IAEA 1999).

By 1976 uranium resources of Pakistan were calculated at 150 000 t of ore at a grade of 0.12% U, containing 181 t U based on a cutoff grade of 0.09% U (IUREP 1978). U mining began in Pakistan at Baghal Chur in 1971.

Regional Distribution and Characteristics of the U-hosting Siwalik Group

Continental sediments of the Tertiary Siwalik Group (or System), partitioned into three divisions (see below), provide the only productive uranium host in Pakistan as known so far. This group, 4 600–5 500 m thick, was almost continuously deposited from Middle Miocene to Lower Pleistocene. The Siwalik System or its equivalents in time, respectively, extend continuously along the Himalayan foothills from Assam in the east to southern Kashmir, and across the Indus Valley in Pakistan through the Potwar Plateau and Balillu Plains where they turn southwesterly into the Bannu Basin and then south into the Sulaiman Range. From this point, they continue as a more marine facies to the Arabian Sea.

Siwalik sediments have been denominated differently in different regions: Siwalik System along the outer Himalayas, Manchchar System in Sind, Mekran Series in Baluchistan, Dihing Series in Assam, and Irrawady System in Burma.

The Siwalik System is a typical sequence of flood-plain sediments of major rivers that was deposited in the foredeep between the Indian Shield and the rising Himalayas and other ranges to the west and south in Pakistan. These fluvial facies grade into shallow marine equivalents in southwestern Pakistan. Fluvial-lacustrine sediments comprise compacted sands, clays, and conglomerates that originated from a wide range of sedimentary, metamorphic, and igneous rocks. A notable feature is the common occurrence of plant and animal remains, locally in considerable profusion. Pyroclastic layers up to several meters thick occur at several levels within the Middle Siwalik System in various areas. During later phases of the Himalayan Orogeny, the Siwalik strata have been folded, faulted, and overthrust, and rest with marked unconformity upon older formations.

Intermittent U mineralization in Siwalik sandstones, mainly in the Middle Siwalik Dhoj Pahan Formation, is known for at least 1 000 km along the sinuous outcrop of this group from 50 km south of Dera Ghazi Khan along the Sulaiman Range, to the Bannu Basin and other areas to the north in Pakistan, and further to the east within India.

9.1 Sulaiman Range, Dera Ghazi Khan District, Punjab

The Dera Ghazi Khan District lies in the Sulaiman Range, a prominent morphological element in the Sulaiman physiographic province in central Pakistan. Numerous radioactive anomalies, some with visible U minerals, are spread over an outcrop length of more than 160 km along the foothills of this range. They include about a dozen small blanket sandstone-type U deposits confined to a single horizon near the base of the Middle Siwalik Member in a N-S strip to the west of the town of Dera Ghazi Khan. Reported deposits include Baghal Chur (or Baghal chor), Rakuchar, Rakhi Munh, Nangar Nai, Kaha Nalo, Bajanpur; and, located to the north of the district, Taunsa (Fig. 9.2). Taunsa is a recent discovery from 2000/2001.

Most resources of the early discovered deposits are exhausted. Some early mining of these deposits was by conventional open pit and underground methods to depths of 150–200 m and later by ISL techniques and produced an estimated total of some 800 t U. At a cutoff grade of 0.03% U, the ore had grades of 0.1% U as maximum. ISL operations began at Rakhi Munh in 1995 and were tested at Nangar Nai in 1997.

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Regional Geological Setting of Mineralization

Rocks from Jurassic to Pleistocene age occur in the Sulaiman physiographic province, the central core of which is marked by mafic and ultramafic intrusions. The Middle Miocene to Lower Pleistocene Siwalik Group is exposed in the Sulaiman Range as a narrow north-south trending belt, some 300 km long and dipping to the east. This group has been tripartitioned into an Upper, Middle, and Lower division (Moghal 1974, based on Wadia 1961):

Upper Siwalik Division, 1 800–2 400 m thick: Coarse boulder conglomerates, thick-bedded earthy clays and silts, whitish grey sands, and grit. The Upper Siwaliks are generally more argillaceous than the underlying strata, and, in the Dera Ghazi Khan District, a thick, extremely coarse, siliceous-boulder conglomerate caps them.

Middle Siwalik Division, 1 800–2 400 m thick: Thick, massive beds of grey arenites (sandstone, subarkose, subgreywacke) intercalated with minor drab and grey clays and shales as well as some thin conglomerate and hard sandstone lenses. The sands are soft, friable, poorly sorted, and cross-bedded; the matrix is highly variable, much of it consists of hard calcareous concretions but most of the rock is soft.

The Middle Division is subdivided into the Dhok Pathan Formation and the underlying Nagri Formation. Both consist mainly of subgreywacke and lithic arenite but are differentiated by their fine-grained facies that comprise mudstone and siltstone with rare clay in the Dhok Pathan Formation and clay/siltstone in the Nagri Formation. Pyroclastic constituents occur in both formations.

Lower Siwalik Division, 1 500 m thick: Fine-grained, more or less consolidated, micaceous sandstone interbedded with abundant bright red, brown, and purple shales and minor conglomerates.

Silicified wood debris and tree trunks are abundant throughout the Siwalik sandstones whereas leaf remnants occur preferentially in the shales. In the Baghal Chur area, the wood and logs are almost entirely limonitized to soft, earthy ochre.
Folding of the Siwalik sediments resulted in the formation of a series of asymmetrical anticlinal and synclinal structures of a general northerly trend. Baghal Chur and other U deposits are located in an asymmetrical syncline stretching for approximately 300 km along the eastern flank of the Sulaiman Range. Superimposed secondary folding extends across all structures and, at Baghal Chur, has resulted in a slight rise of the large syncline causing it to have a double plunge. The depression north of the bulge is denominated *Barthi Basin* and to the south *Baghal Chur syncline*. Strata are only gently tilted over most of the two synclines but they steepen abruptly with dips of 30–60° on the western (Sulaiman anticline) and eastern (Zinda Pir anticline) sides. The Upper Siwalik Member is absent within the crest of this bulge.

Although U anomalies are found in a basal Middle Siwalik sand Horizon/Dhok Pathan Formation all along the major syncline, all U deposits referred to above occur south of the minor structural rise except for Tausa, which is situated further to the north. Baghal Chur is in terrane of gentle dip while the Siwaliks have dips approaching 50–60° at the other U deposits/occurrences to the south.

**9.1.0.1 Baghal Chur**

The blanket sandstone-type Baghal Chur deposit lies about 40 km NNW of Dera Ghazi Khan. Original resources are not published but are assumed to have been on the order of a few hundreds tonnes U at grades of 0.05% U. The deposit was mined from 1971 to 1999 by conventional methods and is depleted.

**Geological Setting of Mineralization**

Baghal Chur is situated in the asymmetrical Baghal Chur syncline; its eastern (Zinda Pir) flank dips 30–50° W while the major portion of the western limb, that hosts all U lodes, shows gentle and uniform 5–10° easterly dips which, however, increase sharply near the western anticline.

Host rocks are fluvial-lacustrine sediments of the Dhok Pathan Formation, Middle Siwalik Division in which U mineralization is confined to an NE-SW-striking and 5–10° SE dipping arenite horizon, about 60–75 m thick, termed Baghal Chur Sand. Shale beds occur below (Bogo Shale) and locally above (Vidor Shale) the sands (Fig. 9.3a).

The *Baghal Chur Sand* was deposited primarily as sheets by southerly flowing rivers. It is a light grey, poorly to well sorted, commonly medium- to fine-grained, soft, and friable subarkose or subgreywacke. Major constituents are quartz, feldspars (10–25% plagioclase, microcline, orthoclase), muscovite, and biotite. Lithic rock fragments of magmatic and metamorphic provenance are common and include chips of occasionally pyritiferous slate and carbonaceous schists. Some rock fragments may represent diagenetically altered volcanic tuff.

Accessory minerals occur in a large variety and are often dominated by magnetite. Based on frequency of feldspars or lithic fragments the sands may be defined as subarkose,
subgreywacke, or sandstone. The detrital components are cemented to variable extent by calcite with subordinate but fairly common heulandite; in some sections cement is absent while in others the sand is relatively well cemented. Erratic pebbles of quartzite, limestone, or calcareous clay pellets are sporadically distributed throughout the section. Some interlayers consist of a friable, medium to coarse grained, siliceous sandstone without rock fragments. This facies is rich in biotite, and muscovite, disseminated pyrite partly as aggregates up to 1 cm in diameter, and plant debris are common. The organic debris is frequently pyritiferous.

The arenite horizon contains numerous intercalated, pinkish lenses, commonly 0.5–1 m, locally up to 3 m thick, composed of quartzite and limestone pebbles in a sandy, silty, and clayey matrix. These lenses persist in a N-S direction for several tens to over a hundred meters, but pinch out rapidly in perpendicular direction, and are thought to mark paleochannels.

The Bogo Shale is grey, locally silty shale, containing siltstone lenses about 1 m thick. It attains a thickness of 12 m at the deposit, but elsewhere it thins considerably. The Vidor Shale, about 25 m thick, is brown to dark brown, locally also silty, and more continuous than the Bogo shale.

**Host Rock Alterations**

Surficial oxidation is the most prominent alteration feature above the present-day groundwater table (some 30 m deep). In this zone, plant remains including logs can be completely replaced by earthy iron (hydro)oxides, and magnetite is commonly martitized.

Other alteration phenomena are of highly variable but mostly minor degree and include argillization, sericitization, silicification, desilicification, calcitization, sulfidization, zeolitization, and barytization. To what extent these alterations are related to diagenetic, mineralizing, and/or other processes remains unclear since there is no color or mineral change noticed at the sites of mineralization.

Some typical alteration features are as follows: Feldspars, particularly plagioclase, are altered to sericite and/or calcite, and to a fine-grained unidentified material. Some schist fragments are extensively replaced by calcite and occasionally by heulandite. Calcitization with subordinate zeolitization (clinoptilolite, heulandite) cement variably the host sands. Quartz grains are corroded. Bones and rocks are partly silicified. Some montmorillonitized rock fragments may represent diagenetically altered volcanic tuffs. Sulfidization is reflected by pyritized plant debris and disseminated pyrite that occurs in part as aggregates up to 1 cm in diameter.

**Mineralization**

Uranium(-vanadium) mineralization occurs above and below the groundwater table, respectively, in oxidized and non-oxidized greywacke in which schist fragments, biotite and feldspar predominate. In both environments, mineralization is out of equilibrium.

**Non-oxidized mineralization:** Pitchblende and coffinite are the principal U minerals in the non-oxidized zone. In addition, uranium is adsorbed by goethite, hematite, martite, biotite, clay minerals, and plant remains. An appreciable uranium content is also bound in zeolite (clinoptilolite, heulandite) that occurs as
discrete diagenetic crystals in pore cavities. Associated minerals include anatase, calcite, hâggite, and an expanding (vanadiferous?) clay mineral.

Uranium minerals commonly form a skin around and line cavities within partially or completely altered plagioclase. They typically occur also within quartz-mica schist fragments particularly in those with carbonaceous material. Most highly mineralized samples comprise carbonaceous rock fragments that are almost completely replaced by pitchblende. Interstices within the host rock are also frequently lined with pitchblende, and in both cases pitchblende exhibits a micro-spheroidal habit.

Hâggite is the major vanadium mineral in the non-oxidized ore besides a possibly vanadiferous clay mineral. Both coat detrital grains while hâggite typically also occurs as cavity infillings and as acicular crystals dispersed in a blue-grey clay coating.

Analyses of selected bulk samples of ore show a range from 760 to 2 000 ppm U, 570–9 800 ppm V, 10–40 ppm Cu, and 5–30 ppm Th (Basham and Rice 1974). Carbonate content is 5% and more and the mineralized horizon has a sand-to-shale ratio of 4:1.

Oxidized mineralization: Tyuyamunite is the principal U mineral but some carnotite occurs occasionally. These minerals, in the form of a greenish-yellow amorphous powder, coat grains, pebbles, and clay pellets, impregnate the interstices between clasts, and locally also associate with crossbeds of heavy minerals. In the latter case, bands of yellow U minerals about 1 cm thick follow above or below, or on both sides 5–10 mm thick black, primarily magnetite, heavy mineral bands and crossbeds.

An appreciable amount of U is adsorbed, however, by earthy iron oxides and or organic debris replaced by similar ferruginous phases. Completely limonitized plant remains, wood logs, or individual pieces of silicified bone often have the highest U concentrations. Samples from the oxidized zone contain amounts of U, V, Cu, and Th comparable to those from the unoxidized zone.

Intercalated coarse-grained sandstone barren of rock fragments is only insignificantly mineralized and the only uraniumous material tends to be pyritiferous plant debris. Vanadium values are much lower than in the mineralized zones but Th and Cu tenors are comparable.

### Shape and Dimension of Deposits

The deposit consists of a group of overlapping ore bodies distributed from surface to depths of 150–200 m. Ore bodies are of strata peneconcordant, elongated to amoeba shape (Fig. 9.3b); boundaries are indistinct or transitional. Ore bodies are from tens of meters to more than 100 m long, from 0.3 to more than 3 m thick, and have tenors ranging from 0.04 to over 0.5% U but presumably average on the order of 0.05% U.

### Ore Controls and Recognition Criteria

U occurrences are distributed in a random nature and U mineralization shows a lack of preference for any sedimentary, textural or structural feature of the host rock except for the position near or at paleovalleys. In spite of this situation certain recognition criteria are noticed by Moghal (1974a):

**Host environment**
- Preferential host rock is grey to tan, fine- to medium-grained subgreywacke or subarkose with interbedded grey and red to brown shale of fluvial-lacustrine origin
- Lithic fragments indicate a provenance from igneous and metamorphic terrane
- Grain size is fine to coarse, sorting poor to medium, selective weak cementation by calcite and minor zeolites
- Sand-to-shale ratios are 4:1
- Strata dip with 5–10° at Baghal Chur; at other U deposits in the district dips approach 50–60°

**Alteration**
- Oxidation above the present-day groundwater table
- Silicification, desilicification, calcitization, sulfidization, zeolitization, and barytization
- No color or mineral change at the sites of mineralization

**Mineralization**
- Unoxidized environment: pitchblende, minor coffinite, and adsorbed U
- Oxidized environment: tyuyamunite, sparse carnotite, adsorbed U
- Associated elements: vanadium, possibly selenium (selenite?)
- Fairly high carbonate content particularly above the groundwater table
- Potential reducing agents: sparse, mostly very fine-grained, disseminated pyrite and rare vegetal remains
- Vegetal matter is almost always completely limonitized to soft and earthy ochre
- Blanket-type, strata peneconcordant elongated to amoeba-shaped ore bodies
- Superjacent arrangement of ore lenses
- Apparent relationship of U lenses to paleochannels

**Metallogenetic Aspects**

Following Basham (1980) and Basham and Rice (1974), replacement textures and the evidence of adsorption by earthy phases such as goethite and hematite, clays, and other phases in the unoxidized ore at Baghal Chur indicate an epigenetic precipitation of uranium from pore-water solution in the reducing microenvironment of rare, organic-rich lithic fragments. This is contradicted, however, by the lack of any significant U enrichment in the coarse-grained sand barren of lithic fragments, in spite of considerable amounts of plant debris; unless one assumes that these rocks may represent a position above the permanent water table from which uranium has been leached.

As may be deduced from the common calcite cement, mineralizing solutions were rich in carbonate. The high calcite content in the oxidized zone may be attributed in part to the present (and past?) aridity of the climate that promoted the loss of CO₂ from groundwater and as such would cause precipitation of U by reaction with vanadate ions to form tyuyamunite.

Another scenario may consider epigenetic processes caused by periodic upheaval and related fluctuation of the groundwater
table that led to reworking and concentration of U at a redox interface. Whosoever the mechanism of U transport and deposition, the ultimate origin of the uranium and vanadium is enigmatic.

9.1.0.2 Other U Deposits/Occurrences in the Baghal Chur District and Barthi Basin

Baghal Chur District: Several other U deposits/occurrences are located to the south of Baghal Chur (Fig. 9.2) in the same Middle Siwalik arenaceous Horizon and exhibit, on surface, bright yellow mineralization in lenses mostly elongated along strike. Single lenses can persist for as much as 60 m. At two of these sites, mineralized lenses, both large and small, are scattered over a distance of 3–5 km along the strike, while at others mineralization is scattered over 1 km. The major part of the uranium outlined at these locations has been mined out except for ore bodies at Nangar Nai that, as of 1997, were being tested for exploitation by ISL methods.

The Taunsa deposit was discovered 70 km N of Dera Ghazi Khan city in 2000/2001. Uranium mineralization occurs in a 13 km long stretch within sands of the Siwalik Group. Exploitation is planned by ISL techniques.

The Barthi Basin, located to the north of the Dera Ghazi Khan District, contains in its southern part three areas with widespread radioactive anomalies. The anomalies in each area are spread over a distance of more than 3 km. Uranium mineralization is rare and, wherever noticed, is associated with limonitized wood logs. Conglomerate beds are common in these areas, and are thought to mark braided paleochannels (Moghal 1974a,b).

9.2 Bannu Basin-Surghar Range, NW Pakistan

The Bannu Basin is located in the North-West Frontier Province of Pakistan. It contains the small Qabul Khel, Eagle Hill, and Shanawah sandstone U deposits in the Surghar Range, an eastern marginal hill range of the basin. U showings hosted by Middle Siwalik molasse also occur intermittently over a distance of 3–5 km along the strike, while at others mineralization is scattered over 1 km. The major part of the uranium outlined at these locations has been mined out except for ore bodies at Nangar Nai that, as of 1997, were being tested for exploitation by ISL methods.

The Qabul Khel deposit is located in the plunging, southern part of the Surghar anticline at the eastern margin of the structural Bannu Basin. This basin consists of folded molasse of the Siwalik Group. Ore bodies are hosted by the Dhok Pathan Formation that forms the upper unit of the Middle Siwalik Division. The Dhok Pathan Formation is a cyclic alternating sand-shale sequence that is variably inclined, between 20 and 45° SW, in the Qabul Khel area.

At the deposit, the sandstone beds are 40–60 m and the intercalated shales 10–15 m thick. The sandstones are grey, soft and friable, and the shales dull brown and grey. The shales are silty and often contain variable amounts of volcanic material in the form of bentonite and bedded ash with glass shards.

Uranium is hosted near the top of the Dhok Pathan Formation in the locally termed Qabul Khel Sandstone, a commonly whitish grey, medium- to coarse-grained sublithic to subarkosic arenite with repeated intercalations of fine-grained sandstone, and interpersed calcified hard sandstone lenses, 10–50 cm in thickness and several meters in length. Major arenite constituents include quartz, feldspars, amphiboles, and rock fragments; some carbonaceous matter, micro-fine humic material, and diageneric pyrite occur locally. The calcite content is high as reflected by CaO values ranging from 2.8 to 5.9%. The arenite is poorly cemented, semi consolidated, friable, and bears good porosity and permeability (hydraulic conductivity is 2–4 md−1 and effective porosity 30–40%).

The Qabul Khel Sandstone rests upon the Qabul Khel Shale, 5 m in average thickness and comprised of brownish grey to tan mudstone intercalated with silty mudstone, shale, and siltstone, which contain abundant volcanic ash and some organic matter. The sandstone is covered by the Lakka Manja II Shale, a 5 m thick on the average, finely bedded, grey shale.

Brittle tectonism resulted in numerous strata discordant and some intraformational faults, fractures, and joints in the Qabul Khel area that are filled with sand and are partly calcified but only above the water table.

Mineralization

Coffinite and pitchblende are the principal U minerals in the unoxidized environment below the water table; they occur as pore fillings whereas pitchblende also occurs as micro-fine globules. Uranophane is typical for the oxidized zone. The ore minerals are contained in an assemblage of predominant amphibole, calcite, quartz, mica, and clay minerals. The ore is poorly cemented, largely unconsolidated, and fragile.
Shape and Dimensions of Deposits

The Qabul Khel deposit consists of a number of ore bodies. Some information is published on one ore body that was tested for ISL mining (beginning in 1995).

Ore is hosted by Qabul Khel Sandstone at the contact with underlying shale; these beds strike NW-SE and dip about 27° SW. Ore is located below the groundwater table. The water table is 65 m below the surface and the ore hosting sandstone is under unconfined conditions (Fig. 9.4).

The ore body is of irregular tape-like configuration; it has a NW-SE length of some 200 m, a thickness commonly from 2 to 15 m averaging 6.5 m, persists over a depth interval from 68 to 118 m below the surface, and averages 0.053% U.

The ore follows, in NW-SE direction, the trace of the water table at the contact of the Qabul Khel Sandstone with underlying shale. Most of the ore is concentrated along the interface of the sandstone with the underlying shale, but at places the ore forms another limb penetrating strata discordant into the sandstone for as much as 120 m, parallel to the present-day water table. The hinge portion of the two limbs is bulbous, attains a maximum thickness of up to 24 m, and contains about 80% of the ore. (Fig. 9.4a).

Metallogenetic Aspects

The Qabul Khel uranium deposit is thought to have evolved through multiple reworking by infiltration. Continual leaching and migration of uranium to its present position occurred during successive tectonic activity and related fluctuation of the water table in response to Himalayan tectonism. U precipitation was caused by permeability barriers combined with upward migrating hydrocarbons, which are considered to have provided the required reductants.

9.3 Other Uranium Occurrences in Pakistan

Minor U occurrences are reported from various parts of Pakistan including the following sites:
Kirthar Range, Sind Province, south Pakistan: U mineralization occurs discontinuously over a strike length of 25 km in sandstone of the Lower Manchar Formation in the Karunuk-Sehwan, Rehman Dhora (Aamri), and Wahi Pandi areas. Uraniferous lenses range from 200 to 1,000 m in length. Samples yield from 0.02 to 4% U. U minerals include carnotite, curite, phurcalite, and saleeite.

Shanawah near Karak, Northwest Frontier Province: U mineralization extends over a strike length of 2 km. The average thickness is as much as 17 m and averages 10 m. Grades average 0.04% U. Carnotite occurs in the oxidized zone above the water table whereas pitchblende prevails below the water table.

Kallar Kahar, Salt Range, central-north Pakistan: Uranium occurs in sandstone of the Middle-Late Miocene Kamlial Formation near Kallar Kahar in the Salt Range, some 120 km SSW of Islamabad. The formation consists of purple-grey and brick red sandstones interbedded with purple shales. Partly calcified and non-calcified sandstones that contain abundant organic matter and more or less devitrified volcanic material host the U mineralization.

Maraghzar Area, north Pakistan: A vein system with U concentrations cutting across the Swat granitic gneiss complex occurs in the high mountains at Maraghzar area in the Swat region, but depths and strike continuity remain to be established.

Sallai Patti Carbonatite, north Pakistan: Several radioactive carbonatites have been found in northern Pakistan including one near Sallai Patti village in Malakand Agency. The Sallai Patti carbonatite is a sheet-like body with moderate to vertical dip, from 2 to 30 m in width, and about 12 km in length. It was intruded along a NW-SE contact fault between granite and schist. Another elongated carbonatite body, 2–7 m thick and intruded in schists, parallels and joins the main carbonatite body in the eastern and western parts of the area. Uranium mineralization is structurally controlled and can be traced along both the strike and dip of the main carbonatite body. Pyrochlore is the main source of radioactivity. The Sallai Patti carbonatite contains 70% calcite (68% CaCO3), 0.4% pyrochlore, (200 ppm U, 600–800 ppm rare metals), 7.1% apatite (3% P2O5, 0.2% REE), and 5.0% magnetite (3.0% Fe). U resources are speculated at a few thousand tonnes uranium at an average grade of 0.02% U (Moghal 2001).

References and Further Reading for Chapter 9 · Pakistan

For details of publications see Bibliography.
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