PAKISTAN

Geography

Pakistan has land borders with Afghanistan, China, India, the Islamic Republic of Iran and borders the Indian Ocean. The country is divided into the Northern Highlands, Punjab and Sindh Provinces of the Indus River Plain and the Balochistan Plateau.

The Northern Highlands consist of parts of the Hindu Kush, the Karakorum (K2 or Mount Godwin Austen), which, at an elevation of 8611 m, is second highest peak in the world. The north-western tip of the Himalayas is marked by the 8126 m peak of Nanga Parbat. The terrain is very rugged and in most parts access is extremely difficult. A road connection between Pakistan and China (Friendship Highway) follows the valleys of Gilgit and Hunza and crosses the Karakorum (Kundjirab Pass).

The western part of the Northern Highlands belongs to the Frontier Province. A road connection from Islamabad and Rawalpindi through Peshawar to Afghanistan passes the Khyber Pass, which has been traversed since antiquity. The mountainous area known as the Sulaiman Range extends along the western part of the country, forming the border with Afghanistan. Its southern continuation is found in the ranges of Balochistan.

The Indus Plain extends south of the Northern Highlands and forms almost half of the country, occupying the eastern part. Beginning at the Salt Range, south of Islamabad/Rawalpindi, the Indus Plain continues south through Punjab and Sindh Provinces, discharging into the Arabian Sea south of Karachi, the industrial centre of the country.

The Indus River has a length of ~3200 km and, together with its tributaries, forms the backbone for water supply to the population centres and for agriculture. The Indus Plain has been inhabited for ~5000 years. The largest dam on the Indus River is at Tarbela, ~75 km NW of the capital. The dam has two functions: electricity generation and flood prevention.

The area of Balochistan covers the eastern part of the Iranian Plateau and extends from the border with the Islamic Republic of Iran up to the Sulaiman Range. Being a dry, mountainous region, the density of population is very low. Large expanses are desert.

The climate of the country varies according to geographic position and elevation. In general, four seasons are observed: (i) a cool and dry winter from December to February, (ii) a hot, dry season from March to May, (iii) a rainy monsoon season in the SW from June to September, and (iv) a more moderate rainy season from October to November. In Punjab, the winters tend to be cold. The summer period can be very hot and reports of temperatures rising to more than 50°C have been recorded in June for Multan.

Roughly one quarter of the country is arable land, which is supported by an extensive system of irrigation. Cotton, wheat, rice and a number of other grains are grown, together with various vegetables and fruits. Energy resources include oil and gas. Chromite and rock salt are some of the important mineral resources exploited [1–3]

Geology

General

The country has a complicated geological history, which relates to the movements of tectonic plates. A more comprehensive description is provided in Ref. [4].

The eastern and southern parts of the country, mainly Sindh and Punjab, belong to the Indian Plate, which formed part of Gondwana. The provinces in the east and NW, Balochistan and Frontier Provinces, are mainly located at the edge of the Iranian Plateau, which belongs to the Eurasian Plate. The mountainous regions are mainly the result of uplift due to tectonic movement. The most prominent example of this is the mountain ranges in the north being uplifted by the movement of the Indian Plate towards the rigid Asian Block.

As a result of plate tectonics, Pakistan features several thrust zones with subductions and intrusions of basic material, believed to be of mantle origin.

The oldest rocks have been found in the Nanga Parbat Massif, south of the Main Mantle Thrust Zone, which have been dated at 2.5–1.85 Ma. The rocks are highly metamorphosed and exhibit frequent instances of granitization. In Azad Kashmir and Hazara, Proterozoic rocks related to the Main Central Thrust Zone have been mapped. West of the Indus River, granitic intrusions dated at ~500 Ma have been found.

In summary, the geological development in this part consists of an Early Proterozoic orogenic event succeeded by intrusions of granite. In the Himalayas, one orogeny has been dated to Late Proterozoic–Early Cambrian and is associated with magmatic rocks. Another orogeny has been compared with the Pan-African event and dated to ~460 Ma, and this has produced granitic rocks and extensive metamorphism (Figure 1).

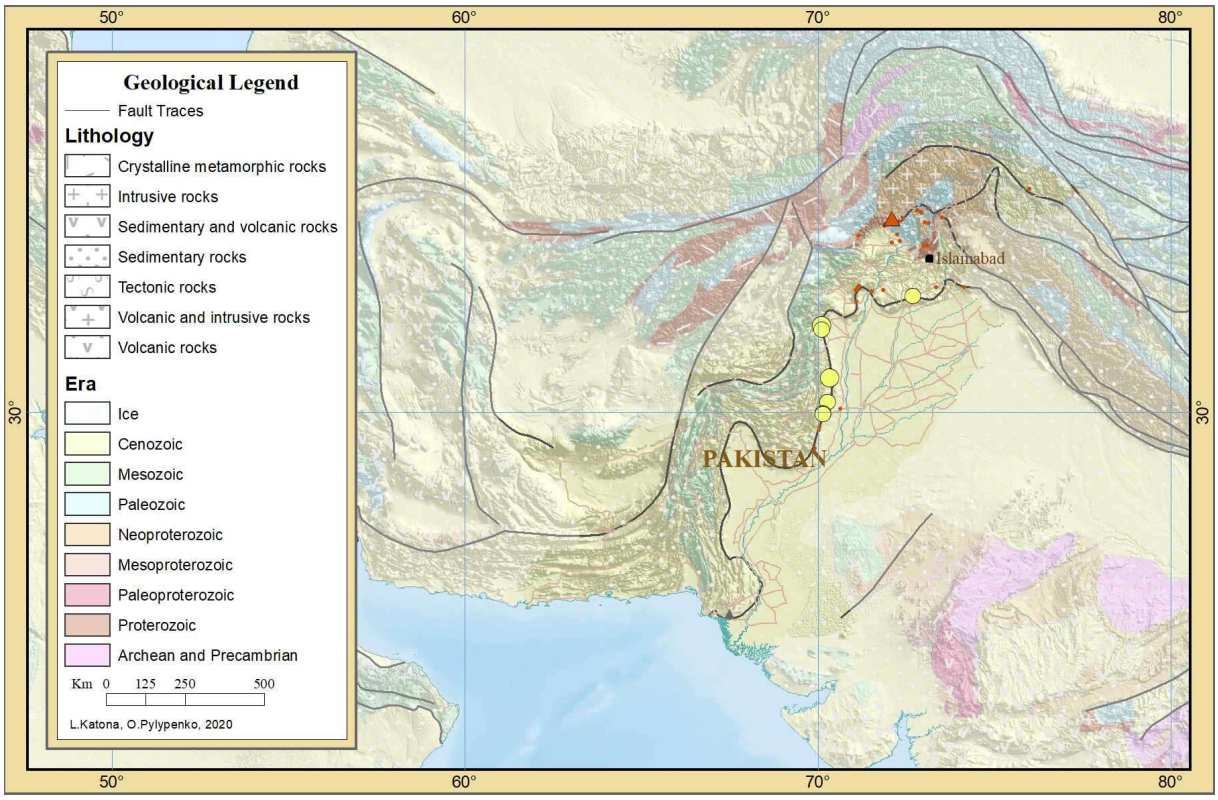


FIG. 1. Regional geological setting of Pakistan showing the distribution of selected uranium deposits and occurrences. For the general uranium deposit and occurrence legend see World Uranium Geology, Exploration, Resources and Production, IAEA, 2020. A general global geological legend is shown although not all geological units necessarily occur on this particular map.

Three major orogenic episodes occurred during the Cretaceous and Tertiary periods as the result of mountain building, e.g., in the Himalayas and in the Karakorum. The third episode, in the Lower–Middle Miocene, was probably the most severe. In the area south of the Karakorum, the well known Kohistan Island Arc Complex was developed.

In the Peshawar region, extensive alkaline igneous activity has been dated at 40 Ma and emplacement of several intrusions of carbonatites at 30 Ma.

In the Main Mantle Thrust Zone, post-Hercynian events have been reported. In particular, subduction processes of Late Cretaceous age resulted in ophiolitic magmatism.

Sedimentary rocks were deposited at various periods. The sedimentary processes are not uniform in the various sedimentary basins of the country. Continuous sedimentation from the Precambrian to the Upper Palaeozoic has not been found in all of them.

During the Mesozoic, sedimentary basins were developed in the Sulaiman Range, the Kohat-Potwar Salt Range and in the West Pakistan Fold Belt. Mixtures of marine and terrestrial sedimentation occur, frequently interbedded with volcanic rocks. Overthrusting and nappe formation result from tectonic movements.

During the Cenozoic, the closure of the Tethys Sea was recorded, manifested by a variety of sedimentation processes, depending on the region. In the Indus Basin, a change from Palaeogene marine sequences towards terrestrial formations in the Neogene has been found. In Balochistan, mostly marine flysch type sedimentary rocks occur [4].

Geology favourable for the formation of uranium deposits

In the foredeep of the mountain ranges, during the Middle Miocene–Lower Pleistocene, a 4500–5000 m thick sedimentary unit of Siwalik strata, or their equivalent, was deposited. This unit consists of clastics derived from the erosion of the hinterland and is made up of sands, conglomerates and clays, which are typical for flood plain sediments of river systems [1, 2].

The Siwaliks and their equivalents extend over large areas, from Rawalpindi in the north through the Potwar Plateau and Sulaiman Range to Quetta in the south. Equivalents are found at the coast of the Makran/Arabian Sea and in the Kithar Range of Sindh, NE of Karachi [2]. The Siwalik sandstones have been investigated for their uranium potential.

In 1959, exploration by carborne survey discovered anomalies in Middle Siwalik sandstones near Dera Ghazi Khan in an asymmetric syncline on the eastern flanks of the Sulaiman Range. Subsequently, at Baghal Chur, uranium mineralization was found which justified mine development. The mineralization at Baghal Chur is hosted in 2000–2500 m thick Middle Siwalik strata and restricted to the so-called Baghal Chur sand (70–80 m thick). The Baghal Chur sand is light grey and medium- to fine-grained and enclosed by clays above and below [6].

Anomalies have been found in other areas covered by Siwalik strata and development has been reported for the mineralization occurring at Qabul Khel (Bannu Basin) in North-West Frontier Province [5].

In northern Pakistan, several granitic intrusions and carbonatites located south of the Main Mantle Thrust Zone have exhibited a variety of uranium showings, some in pegmatites and others in clayey material (areas around Tarbela, Mansehra and Malakand). Migmatites at several locations also show varying degrees of uranium enrichment [14]. However, to date, none of the above mentioned anomalies are of any economic importance. Precambrian graphitic metapelites in the Kagan valley and near Muzaffarabad in Azad Kashmir have exhibited higher levels of radioactivity associated with disequilibrium due to leaching of pyrite [4].

Calcrete type mineralization has been found in the Thar Desert, although details are unavailable [17].

Uranium exploration

Exploration for uranium started in the 1950s and has been extensive. Detailed figures on expenditures and drilling campaigns are not available. However, it is reported that drilling at Baghal Chur amounted to several thousand metres [6].

The IAEA and the United Nations Development Programme carried out exploration in the Baghal Chur area in the 1970s which included the drilling of 1029 holes totalling 43 000 m [1].

It is not reported to what extent other anomalies have been investigated. It can be assumed, however, that at least ground radioactivity surveys have been carried out. Exploration in the area surrounding Baghal Chur (over 50 anomalies or groups of anomalies) was extensive in the 1970s although it has been stated that the area was not totally explored in the campaigns conducted in this period [1].

In the second half of the 1990s, exploration continued in areas of the Siwalik sandstone in Kashmir, the Potwar Plateau, Bannu Basin and the Sulaiman Range. Under the guidance of an IAEA supported programme (platform survey), a prospective area in the Potwar Plateau was reduced, first to 2000 km², and later to 400 km² [8].

In the Bannu Basin, in situ leaching (ISL) methods have been applied using ammonium bicarbonate and hydrogen peroxide to recover uranium.

In the 1999 Red Book [9], it is reported that exploration was successful in discovering an uraniferous horizon in the Kamlial Formation of the Salt Range. The finding of a uranium-bearing vein system in the granitic rocks of the Maraghzar area in the Swat district has also been reported [9].

In July 2017 CNNC signed a framework agreement with PAEC for technical cooperation in the exploration and development of uranium resources [10].

Uranium resources

Pakistan has not provided the official reports required for the evaluation of resources for the Red Book, neither for identified resources nor for undiscovered or unconventional resources.

In an evaluation in 1976, the resources at Baghal Chur were estimated at ~180 tU, based on a cut-off grade of 0.08% U.

Studies were also undertaken to investigate the recovery of uranium from carbonatites such as the Sellai Patti intrusion which are estimated to contain a few thousand tonnes of uranium at average grades of 0.02% U. The studies have shown that the uranium content can be upgraded by a factor of 150 [8].

Potential for new discoveries

Exploration for deposits occurring in continental to lacustrine or fluvial sandstones has shown that uranium mineralization occurs in the Siwalik sandstones and their equivalents. At present, it is not known whether generally favourable sandstones have been explored to the required level. Thus, it remains an open question as to whether exploration would again be worthwhile for Siwalik type mineralization. Examples found so far indicate that the Siwaliks seem to be limited in potential, with any mineralization being of restricted tonnage and of relatively low grade. However, ISL methods have been developed and have proven economic in the recovery uranium, even from small and low grade deposits [11].

As exploration has shown anomalies to be present in graphitic metapelites, further investigation may be worthwhile to determine to what extent leaching has occurred and what model of possible enrichment of uranium may be applied.

The anomalies in calcrete in the Thar Desert could also be of interest in view of the recent success recorded on the calcrete type mineralization at Langer Heinrich in Namibia.

Uranium production

Uranium production started at Baghal Chur in 1978 using a pilot plant with a yearly capacity of 30 tU [10]. Official production figures, however, are not available. It was reported that production started in 1971, with 30 tU/year produced between 1971 and 1991. In 1992, production was estimated at 23 tU annually up to the present day. Other unofficial information assumes an annual production of 40–45 tU from three ISL operations [12]. From 2008 to 2017, production is estimated to be approximately 45 t U/year (Figure 2) for a total of 1576 tU [13].

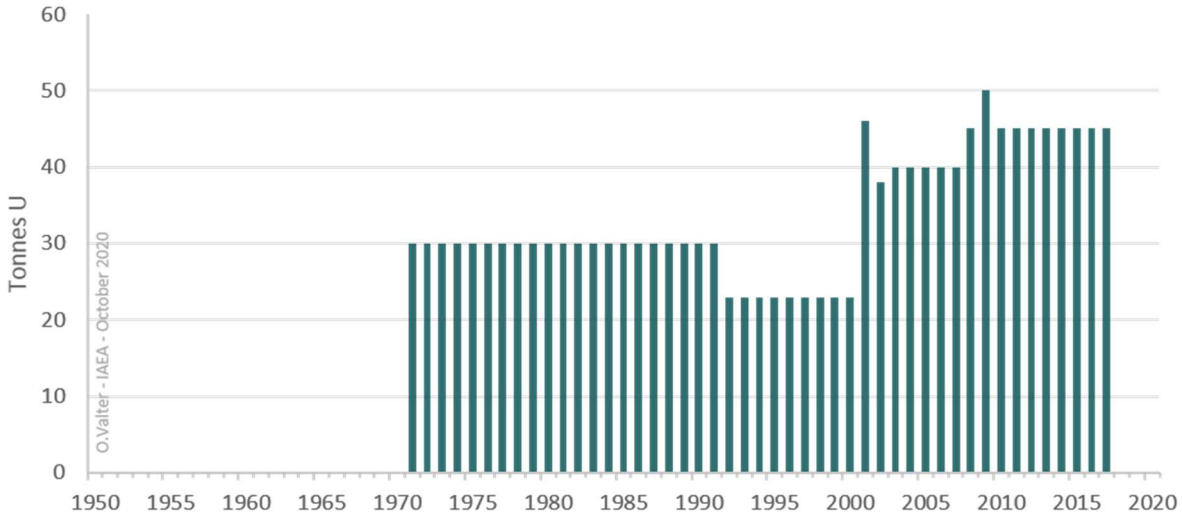


FIG. 2. Historical uranium production in Pakistan.

References

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, International Uranium Resources Evaluation Project, IUREP, National Favourability Studies: Pakistan, IAEA, Vienna (1976) 17 pp.

[2] OECD NUCLEAR ENERGY AGENCY–INTERNATIONAL ATOMIC ENERGY AGENCY JOINT STEERING GROUP ON URANIUM RESOURCES, World Uranium: Geology and Resource Potential, Report on Phase 1, International Uranium Resources Evaluation Project (IUREP), Miller Freeman Publications, San Francisco (1980) 524 pp.

[3] CENTRAL INTELLIGENCE AGENCY, The World Factbook: Pakistan, Washington, DC, https://www.cia.gov/library/publications/the-world-factbook/index.html.

[4] BENDER, F.K., RAZA, H.A., Geology of Pakistan, Borntraeger, Stuttgart (1995) 41 pp.

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, World Distribution of Uranium Deposits (UDEPO), with Uranium Deposit Classification, 2009 Edition, IAEA-TECDOC-1629, IAEA, Vienna (2009).

[6] MOGHAL, M.Y., "Uranium in Siwalik sandstones, Sulaiman Range, Pakistan", Formation of Uranium Ore Deposits (Proc. Int. Symp. Athens, 1974), IAEA, Vienna (1974) 383–403.

[7] TAUCHID, M., "Uranium resources potential for Asia and the Pacific", Uranium Deposits in Asia and the Pacific: Geology and Exploration (Proc. Tech. Mtg Jakarta, 1985), IAEA, Vienna (1988) 21–38.

[8] OECD NUCLEAR ENERGY AGENCY, INTERNATIONAL ATOMIC ENERGY AGENCY, Uranium 1997: Resources, Production and Demand, OECD, Paris (1998).

[9] OECD NUCLEAR ENERGY AGENCY, INTERNATIONAL ATOMIC ENERGY AGENCY, Uranium 1999: Resources, Production and Demand, OECD, Paris (2000).

[10] WORLD NUCLEAR ASSOCIATION, Country Reports Pakistan (2019).

[11] BASHAM, I.R., RICE, C.M., "Uranium mineralization in Siwalik sandstones from Pakistan", Formation of Uranium Ore Deposits (Proc. Int. Symp. Athens, 1974), IAEA, Vienna (1974) 405–418.

[12] OECD NUCLEAR ENERGY AGENCY, Forty Years of Uranium Resources, Production and Demand in Perspective: The Red Book Retrospective, OECD, Paris (2006) 280 pp.

[17.13] OECD NUCLEAR ENERGY AGENCY, INTERNATIONAL ATOMIC ENERGY AGENCY, Uranium 2018: Resources, Production and Demand, OECD, Paris (2018).