The Phosphate Potential of Afghanistan

Introduction

Afghanistan is situated on the junction between the Indian and Eurasian crustal plates and is composed of a series of terranes (Figure 1) that broke away from the main Gondwana supercontinent before colliding with and being accreted on to the Eurasian plate. The accretionary events started in the Cretaceous and have continued until recent times. The Herat or Hari Rod fault, which runs E-W across central Afghanistan, marks the boundary between Eurasia to the north and the first of these accretionary terranes, the Farad block, to the south; the intervening Paleo-Tethys ocean having been subducted under the Eurasian continent.

Phosphorus, in the form of phosphate, is essential to the growth of plants and phosphate is an importantl component in man-made fertilisers. Agriculture is very important in the Afghan economy and about 80% of the population work in this sector. Imported fertilisers are important in maintaining and increasing farm production and it is estimated that the country imports about 0.5 Mt/year but the potential demand is 1 Mt (Emerging Asia Limited, 2009). A domestic source of phosphate rock would be important in improving Afghanistan's agricultural productivity and reducing its dependence on imports.

The planned smelter at the Aynak copper mine will produce excess sulphuric acid from the sulphur dioxide removed from flue gas and this acid be neutralised by phosphate rock in the following reaction:

$$Ca_5F(PO_4)_3+5H_2SO_4+10H_2O \rightarrow 5CaSO_4.2H_2O+HF+ H_3PO_4$$

Around 1 Mt/year of phosphate rock will be required by the smelter for its planned operation. The phosphoric acid can be used to make mono- or di-ammonium phosphate fertiliser.

At the present time there are no phosphate rock mines or advanced prospects in Afghanistan and this brochure assesses the potential for exploration and suggests prospective areas for the discovery of phosphate deposits.

Phosphate deposits are found in two, very different geological settings:

a. *Sedimentary deposits* provide about 80% of the world's phosphate production and consist of accumulations of apatite formed by biological activity.

b. *Igneous deposits* provide about 20% of global phosphate production and are associated with alkaline igneous rocks, particularly carbonatite complexes, where apatite is an important constituent.

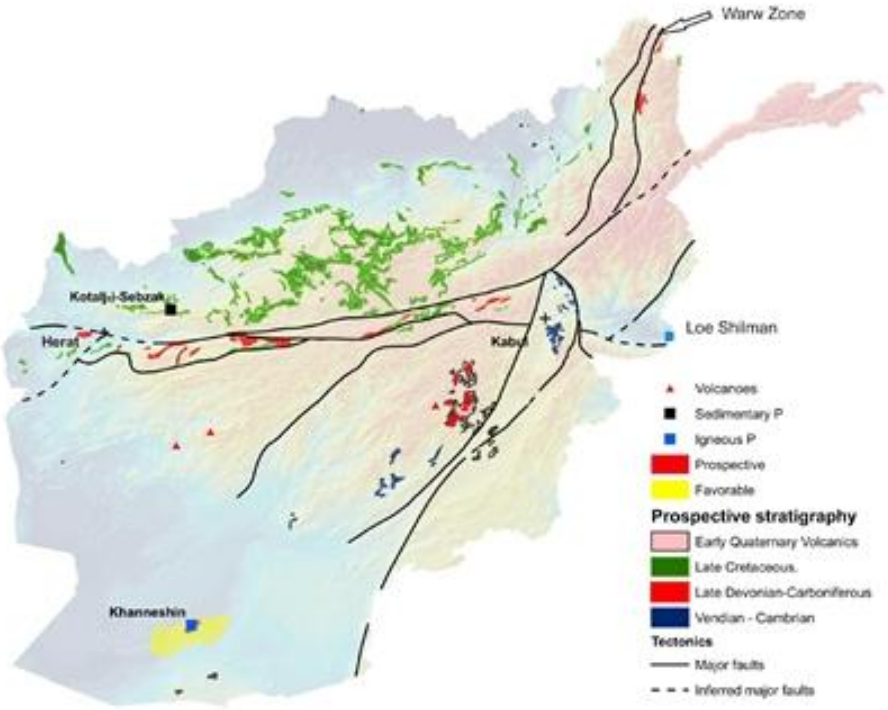

Figure 1. Prospective areas for Phosphate rock on a coloured relief background

Sedimentary Phosphate Deposits

Sedimentary phosphate deposits can form in two different sedimentary environments:

- Type I on the continental shelf platforms or slopes, where upwelling, phosphorus-rich, cold-currents stimulate high organic productivity;
- Type II in estuaries and isolated arms of the sea that are fed by phosphorus-bearing river water.

Age of deposits

The isotopic composition of oxygen in seawater changes with temperature and variation of these isotopes in the past can be used to show how the climate has changed (Figure 2). Formation of sedimentary phosphate deposits has occurred throughout the Earth's history but can be correlated with periods of global seawater warming in the Cambrian-Ordovician, Upper Devonian, Permian, and Cretaceous-Paleogene.

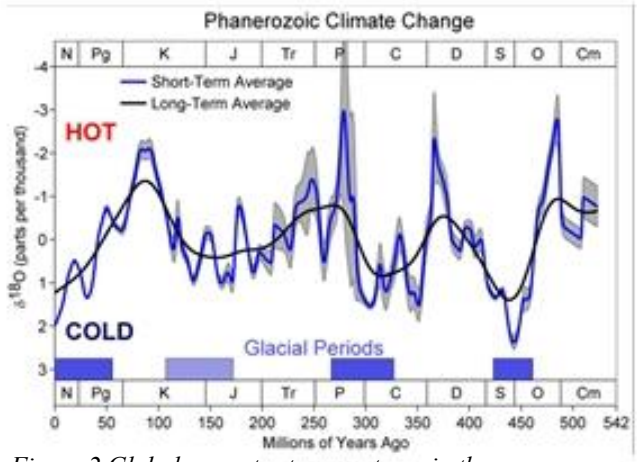

Figure 2 Global seawater temperatures in the Phanerozoic derived from oxygen isotope composition

Paleogeographic situation

Phosphate deposition occurs in warm latitudes, mostly between the 40th parallels. The formation of sedimentary phosphate deposits is highly dependent on ocean currents, which are controlled by the distribution of continent and sea. Therefore, plate tectonic processes have a strong effect on the location of phosphate deposits throughout the geological history. Many deposits occur in long zones that were once along continental margins.

In the Southern Asia region of Iran, Afghanistan, Pakistan and India favourable periods for phosphate deposition, shown by worked deposits or major prospects, are the Infra-Cambrian, Upper Devonian and Upper Cretaceous-Paleogene. The Infra-Cambrian of northern Pakistan and India has a number of deposits, for example the Kakul mine, Hazara basin, NW Pakistan. In Iran the major deposit at Jeyrud in the Alborz Mountains of Iran is of Upper Devonian age and younger phosphate prospects are found in the Cretaceous of the Zagros mountains.

Vendian and Lower Cambrian

Vendian and Lower Cambrian rocks are restricted to the Kabul Block and the Argandab Zone of central and south-eastern Afghanistan (Figure 1). The stratigraphy of these areas has similarities with those of India and Pakistan and they are prospective for phosphate but their areal extent is small and much disrupted by folding and faulting. The Aynak deposit itself is hosted by Vendian-Lower Cambrian rocks of the Loy Khwar Series and detailed exploration for phosphatic rocks should be undertaken around the deposit.

Upper Devonian

In Iran the sedimentary phosphate deposits are hosted by rocks of the Late Devonian Geirud Formation in the Alborz Mountains, which are comprised of sandstones, ferruginous limestones and subordinate black shales (Salehi, 1989). The phosphate horizon, found at the base of the Upper Devonian series, is widely distributed throughout the Alborz Mountains and its thickness ranges from 0.6 to 7.0 m. The black phosphorites consist of rounded pellets and reworked clasts of chemically precipitated apatite and reworked coprolites, bone fragments and grains of phosphatic siltstones (Figure 3). The mineralisation is interpreted as the product of upgrading in a shallow water environment of primary low grade source materials. The phosphate horizon grades between 10 to 25 % P_2O_5 and an initial resource is estimated at 12 million tons of phosphate at 22.5 % P_2O_5 and 34 million tons of phosphate rock at a grade of 11.5 % P_2O_5.

Abdullah et al. (1980) describe the sedimentary rocks of Late Devonian - Early Carboniferous in Afghanistan as a sequence of grey and dark clastic limestones, dolomites, sandstones and siltstones, which were deposited in a shallow water environment. The rocks are frequently very fossiliferous, and the thicknesses of the Upper Devonian - Lower Carboniferous sequences are between 200 and 800 m. Their extent is shown in Figure 1.

Exploration should be concentrated in the Upper Devonian beds, which are the stratigraphic analogue of the Iranian Alborz Mountain sequence.

Figure 3 Polished section of black phosphorite with rounded pellets and reworked clasts (Jeyrud mine, Iran).

Permian

Abdullah (1980) records phosphorite -bearing polymictic sandstones in Permian rocks of the Warw zone, of northernmost Badakhshan, where Permian rocks form a wedge-shaped fault block, 50 km in length and from 2 to 7 km in width. The phosphorite bed occurs near the top of the fossiliferous sequence in the Darrah-i-Begaw valley, Darwaz district. No other information is given and no analysis published.

Upper Cretaceous and Paleogene

As described above, the right conditions for phosphate deposition are met during this period in Afghanistan. During Late Cretaceous time in Northern Afghanistan, there was a continental margin with a shallow marine shelf platform environment (Schreiber et al., 1972) located between the 0° and 40° northern paleolatitudes.

The Upper Cretaceous sedimentary sequence was deposited under a transgressive marine regime and a sedimentary phosphate occurrence is known in Afghanistan at Kotal-i-Sebzak (34°39'30"N, 69°09'E), in Herat Province. The phosphate mineralisation is found within a sedimentary unit of sandstones, limestones and dark grey shales at the base of Upper Cretaceous rocks. The mineralisation consists of a 0.3 to 1 m thick horizon, comprised of irregular phosphate nodules measuring between 0.5 and 6 cm. The nodules contain up to 5 % of non-phosphate inclusions such as glauconite and quartz and the nodules are cemented by carbonate-phosphate material, which also contains about 20 % non-phosphate material, namely glauconite. Throughout the whole horizon, phosphatised fossils such as ammonites, bivalves and gastropods are found. The grade of the phosphate horizon is between 6.2 to 9.7 % P_2O_5.

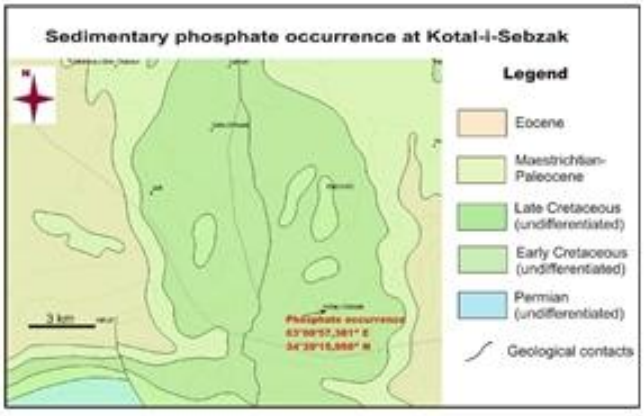

Figure 4 Geological map of Kotal-i-Sebzak occurrence

This phosphate occurrence needs to be geologically mapped, re-sampled and traced along strike using a field geochemical colorimetric method, which was very successful in locating phosphate occurrences in Iran.

Igneous Phosphate Deposits

Alkaline igneous rocks and carbonatites can contain workable quantities of phosphate minerals, generally fluor-apatite, and these are mined, for example, at Siilinjärvi, Finland, Phalaborwa, South Africa and Khibiny Complex, Kola Peninsula, Russia. Most of the igneous complexes are characterised by assemblages of alkali-rich intermediate and ultrabasic rocks and carbonatite, and the complexes are also invariably located close to or within regional linear fracture zones.

Khanneshin Carbonatite Complex

The igneous alkaline complex is of Early Quaternary age and is a strongly eroded strato-volcano, which consists of tuff, agglomerate and subvolcanic carbonatitic igneous rocks. The main carbonatite rock types are soevite, barite-ankerite-fluorite carbonatite and associated tuff, alvikite and associated agglomerate and tuff. The alkaline igneous rocks have high concentrations of rare earth elements, uranium, strontium, fluorine, phosphorous, niobium, and lead.

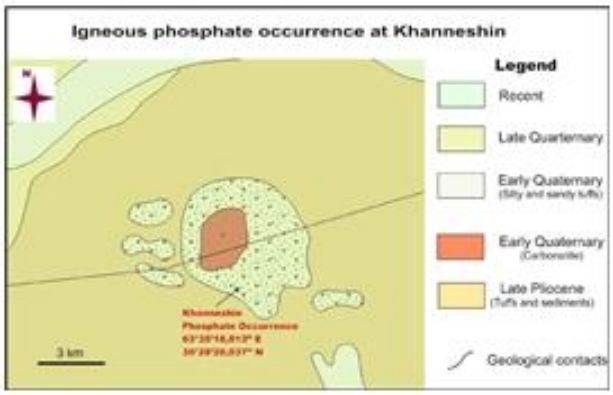

Figure 5 Geological map of the Khanneshin carbonatite

Phosphate is present as apatite, which is common in the Khanneshin carbonatite complex. The major apatite concentrations are in xenoliths composed of magnetite-apatite, and in alvikite, which grades 8.3 % P_2O_5. According to Eriomenko and Chmyriov (1975), there are eight apatite-mineralised zones in the carbonatite complex. Carbonatite phosphate rocks can contain deleterious concentrations of other metals, such as uranium and REE, and may not be suitable for fertiliser production.

Exploration for further carbonatites or alkali syenites should be concentrated adjacent to Khanneshin (USGS permissive tract, Figures 1 and 6), along the Chaman linear fracture zone and in the Lower Quaternary Dashte Nawer Series volcanic rocks (Figure 1). Evidence of carbonatite activity has been observed in the volcanics and a ten-metre horizon of trachyandesite-dacite tuff with up to 30 per cent in carbonate content was found to outcrop in fragments within an area of a few dozen sq. km (Abdullah, 1980).

Loe Shilman (Pakistan Border)

Carbonatite bodies not only occur as circular, plug-like bodies but also as tabular bodies in fold zones. The Loe Shilman carbonatite lies in Pakistan, 50 km north-west of Peshawar, immediately adjacent to the Afghanistan border (Hasan and Asrarullah, 1989). The complex is of Tertiary age and is hosted by Paleozoic metasediments of the Landi Kotal Formation. The carbonatite contains a geologically estimated resource of about 200 Mt of phosphate ore to a depth of 200 m, grading 5 % P_2O_5. Further exploration should be carried out to ascertain the grade and extent of the carbonatite on the Afghan side of the border.

Resources in Afghanistan

At the present time the only identified resource of Phosphate rock is at Khanneshin with the alvikite grading 8.3% P_2O_5. However, the neighbouring countries of Iran and Pakistan have identified economic deposits of both sedimentary and igneous origin and there are indications that similar deposits are present in Afghanistan.

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Figure 6. Aeromagnetic expression of the Khanneshin carbonatite (Peters et al., 2007)

Summary of the potential for Phosphate Rock in Afghanistan

- **Demand for 1Mt of phosphate rock to neutralize excess sulphuric acid at Aynak**
- **Potential igneous phosphate resources at Khanneshin grading 8.3 % P_2O_5**
- **High potential for the discovery of sedimentary phosphate rock in the Upper Devonian and Cretaceous sequences, and, possibly, in the Infra-Cambrian and Permian.**

Contact Details

For More Information Please Contact:
Investment Promotion Directorate
Ministry of Mines
Kabul, Afghanistan
Telephone: +93 (0) 752 076 483
E-Mail: miningenquiries@mom.gov.af
Website: http://www.mom.gov.af

Director General
Afghanistan Geological Survey
Kabul, Afghanistan
Tel: +93 (0) 75 200 1714
E-mail: ags@mom.gov.af

PMU Director
Afghanistan Geological Survey
Kabul, Afghanistan
Tel: +93 (0)796 216 251