→ IAEA

International Atomic Energy Agency

IUREP N.F.S. No. 40
August 1977
Distr. LIMITED
Original: ENGLISH

INTERNATIONAL URANIUM RESOURCES EVALUATION PROJECT

I U R E P

NATIONAL FAVOURABILITY STUDIES

BOLIVIA

77-7436

INTERNATIONAL URANIUM RESOURCE EVALUATION PROJECT

IUREP

NATIONAL FAVORABILITY STUDY

BOLIVIA

CONTENTS

1. INTRODUCTION

(a) Geography

Bolivia has an area of 1,098,580 square kilometers. Its capital is La Paz. The western part of the country is dominated by two ranges of the Andes Mountains, the Cordillera Occidental on the west flank of the high plateau (Altiplano) and the Cordillera Real (or Oriental) on the east flank. The northern Andes average 5,486 meters in elevation; the southern Andes are not as lofty. The Altiplano is 3,658 to 4,267 meters high and 129 km. in average width; it is the largest basin of inland drainage in South America and contains the renowned Lake Titicaca on the Peruvian-Bolivian border. The eastern tropical lowlands or pampas (Oriente) comprise about two-thirds of the country, with rain forest in the northern portion. An intermediate zone of valleys and basins lies between the eastern Andes and Oriente.

(b) Climate

The lowlands of Bolivia have a humid tropical climate. Although the plateau is generally cold and semiarid, summer temperatures may exceed 26.7°C. Rainfall is highly variable seasonally and from year to year; most of it comes in the October-May period, with the southern and eastern sectors of the country receiving more rain than other regions.

(c) Access

Large parts of Bolivia lack adequate rail or road transportation. Most of the 37,075 km. of roads are suitable only for dry weather. The chief highways are the Pan American of 1,134 km. (mostly unpaved) and the 563 km. Cochabamba-Santa Cruz. There are about 3,579 km. of railroad trackage, chiefly on two lines. A railway is being built between Santa Cruz and Trinidad Beni. International flights operate through La Paz airport; there are some additional 95 airfields and landing strips. Thirty large rivers of the Amazon system are navigable in small boats over a total distance of 19,308 km. Steamships traverse Lake Titicaca.

2. GEOLOGY IN RELATION TO POTENTIALLY FAVORABLE URANIUM-BEARING AREAS

Bolivia differs from other Andean countries, like Chile, Peru and Ecuador, in having large areas of Precambrian schists, gneisses, migmatites and granites. These crop out in the eastern part of the country. Parts of these rocks contain banded iron formations (i.e., in the Mutún region) and are probably early Precambrian in age.

Cambrian, Ordovician, Silurian and Devonian sediments are well represented from the border with Peru (14°-15°S, 69°W) to the border with Argentina (22°S, 65°-66°W), along a belt which is the southern extension of the Marañón-Mantaro-Apurimac-Urubamba geanticline of Peru. These rocks are much better exposed in Bolivia than in Peru because they crop out along the Cordillera Oriental. Most are grey, black or greenish marine shales and sandstones with some interbedded continental "red beds". The Cambrian sediments contain purple, pink, white and green quartzites with yellowish-green shales. In the eastern mountains of Bolivia, Ordovician and Silurian sediments overlying the Precambrian rocks contain thickly bedded arkoses and red arkosic sandstones with red jasper and hematite in the upper part ("Serie Jacadigo"). The uppermost Silurian Vila Vila Formation contains a sequence of red quartzitic sandstones.

Permocarboniferous sediments correspond mostly to two continental glacial periods whose sediments are separated by red, yellow and green sandstones with dark grey and red shales. These rocks are distributed in small patches along the Cordillera Oriental and the sub-Andean belt of Bolivia. Permian sediments are marine in their lower part and continental toward the top.

Cretaceous sediments are mostly continental and are preserved only in cores of synclines along the Altiplano and the Cordillera Oriental from the Peruvian to the Argentine border. In general, they consist of conglomerates and red sandstones with interbedded limestones and variegated marls. The Cretaceous rocks in the sub-Andean region (Tucurú) consist of red crossbedded sandstones with calcareous and limonitic cement. There is also a sizeable area of Cretaceous rocks centered at 18.3°S, 60.5°W.

Tertiary rocks are well represented in many parts of Bolivia, particularly

1. in the western part of the country from Peru (17°S, 69°W) to Argentina (22°S, 67°W);

2. along the sub-Andean belt from the border of Peru to Argentina (22°S, 64°W);

3. in isolated patches in the eastern part of the country (i.e., 17.8°S, 60.4°W).

Tertiary continental sediments and volcanic rocks in the western Altiplano range in thickness from 0.3 to 12.0 km. Reddish-brown and red sandstones, conglomerates and shales predominate in the lower part of this sequence, whereas pyroclastic rocks predominate in the upper part. The rocks are folded and covered unconformably by extensive lava flows and ignimbrites. Tertiary sediments in the sub-Andean region characteristically contain conglomerates, with flint clasts, overlain by great thicknesses of red-brown shaly sandstones.

Granitic intrusives are scattered throughout the Bolivian Andes and give radiometric ages spanning from the Triassic to the present. The extrusive igneous rocks consist mostly of rhyolites, dacites and andesites.

3. PAST EXPLORATION

Little systematic exploration for uranium was undertaken in Bolivia until the late 1960's. In 1967, 1968 and 1969 technical assistance was requested from, and provided by, the IAEA. This work led to evaluation of radioactive anomalies in veins of northeast Bolivia and in sandstones in the extreme southern part of the country.

The Comisión Boliviana de Energía Nuclear (COBOEN) was created in 1969 by the government as a vehicle for exploring, mining, beneficiating and selling all radioactive minerals developed in Bolivia. In 1973 the Homestake Mining Co. was employed by the Bolivian government to evaluate the information obtained by COBOEN. In 1974 COBOEN signed a production-sharing contract with AGIP of Italy to explore and eventually mine uranium deposits in concessions covering 50,000 $km.^2$ within the main areas of Tertiary red beds. AGIP carried out airborne geophysical surveys in 1974 and diamond drilling in 1976. COBOEN was assisted in its work by the International Atomic Energy Agency and by the French Atomic Energy Commission.

The purpose of most of the work done so far (see Table 1) has been to explore the extension into Bolivia of the Cretaceous sediments of northern Argentina, in which economic uranium deposits are known, and to follow up indications provided by the pilot survey of the Cordillera conducted by a Swedish consulting group in 1963. The majority of these studies consequently covered the Cordillera Oriental and the Altiplano.

4. URANIUM OCCURRENCES AND RESOURCES

In the northern part of the Cordillera Oriental (from the Peruvian border to about 17°S) several vein deposits have been found containing pitchblende and autunite associated with copper and iron minerals. The most important finds appear to be the Charazani anomalies (averaging 0.2% U_3O_8) and the Urania mine, a former producer of tin and tungsten ores located 70 kms. SE of La Paz (16°44'S, 67°46'W). The geology of the Urania mine is described by Ahlfeld (1954, p. 113) and Ahlfeld and Schneider-Scherbina (1964, p. 84). The Urania vein is up to 5 m wide and cuts phyllitic schists in the vicinity of a granitic stock with associated dikes. Prior to the discovery of uranium, the minerals described from this deposit were pyrrhotite, pyrite, arsenopyrite, sphalerite, chalcopyrite, quartz, tourmaline, wolframite, scheelite and finely disseminated cassiterite. Although the ore reportedly contained over 1% each Sn and WO_3, early attempts to beneficiate it failed due to its mineralogical complexity. The uraninite is found associated with pyrite, marcasite, and hematite. Average grades of 0.1% U_3O_8, locally up to 1.1% U_3O_8, are reported by Mariaca (1977) over vein widths of 0.7 - 1.0 meters and a developed strike length of 250 m. Other radioactive anomalies are reported at Cohuila and Bolsa Negra.

In the central part of the Cordillera Oriental radioactive anomalies associated with phosphates, organic matter and sulphides have been detected in the Tapacari zone (17°3'S, 66°36'W) in Ordovician black shales. Indications of uranium are also known from the Miraflores syncline in Potosi. The most important anomalies found so far are, however, in the Cordillera de los Frailes (19°-20°S, 66°-67°W), an extensive area (10,000 sq. kms.) of Tertiary rhyolitic lavas, tuffs and pyroclastic rocks. In this region, radioactive anomalies have been found at the Cotajes mine, Carwaycollo, Willakillo, Tholapalca, Marquez, Huancarani, Los Diques and Asunción. Mineralization consists of pitchblende, torbernite, coffinite and autunite, with grades around 0.09% U_3O_8, and is associated with iron, manganese, arsenic and molybdenum minerals, as well as smoky quartz and barite in fault structures. Cotajes is the site of a metallurgical pilot plant for uranium recovery.

In the southern part of the Cordillera Oriental autunite- and metaautunite-containing veins east of Tupiza (21°25'S, 65°44'W) have grades up to 0.2% U_3O_8 in strongly fractured Tertiary rhyodacitic lavas.

In the Altiplano many radiometric anomalies have been detected within the Tertiary red beds in association with copper ores and organic matter in paleochannels. The principal anomalies in the northern Altiplano occur in the vicinity of the Corocoro (17°10'S, 68°30'W, Cerro Kachaca, 15 kms east of Corocoro) and Chacarilla (17°33'S, 68°15'W) mines, together with significant molybdenum anomalies. In the southern Altiplano the most important anomalies are at the Kollpani mine and at Agua de Castilla.

5. PRESENT STATUS OF EXPLORATION

In 1977 AGIP had completed 48,000 km^2 of aerial surveys under a 1974 agreement with COBOEN which also provides for subsequent uranium production. Some drilling was also done. The work was concentrated in four areas - two in the Altiplano, one in the sub-Andean region near the Argentine border and one in the lowlands of Santa Cruz.

COBOEN is drilling in the Cordillera de los Frailes, Potosi Department. A pilot plant has been set up at the Cotajes mine (at los Frailes) to yield metallurgical data and practical experience which can be used to bring a commercial plant into operation in the early 1980's. Pilot plant completion is expected in August, 1977.

In addition to AGIP, German, French and North American mining companies have been negotiating with COBOEN.

Although the tempo of exploration has accelerated during the past few years much more work is needed for a realistic uranium assessment. By way of illustration, in 1972 it was estimated that only 25 percent of the country had been mapped geologically and only 5 percent had received adequate mineral exploration.

6. AREAS FAVORABLE FOR URANIUM MINERALIZATION AND POTENTIAL FOR NEW DISCOVERIES

The most obvious targets for uranium exploration are the Tertiary red beds of the Altiplano, particularly in the vicinity of intersecting, scattered granitic stocks and where the red beds are associated with rhyolitic volcanic rocks, i.e., on the western margin of the Alta Meseta de los Frailes. The metallogenic maps of Ahlfeld (1954) and Ahlfeld and Schneider-Scherbina (1964) show a string of "red-bed" copper deposits in this environment extending from the border with Peru to Argentina. Particularly tempting targets for uranium exploration exist around the Amistad mine near Sevaruyo (19°30'S, 67°W), around the volcanics at San Pablo (21.5°S, 66.6°W), in the area of Carangas (19°S, 68.7°W), and around the Zorro and Anaconda mines (17.3°S, 69.2°W).

Also attractive targets for sandstone-type uranium deposits are the patches of Carboniferous, Permian and Cretaceous red beds preserved within the Paleozoic rocks along the eastern Altiplano and in the Cordillera Oriental from the border with Peru to Argentina. This would include the areas northwest of Potosi where the Cretaceous sediments are associated with rhyolitic volcanics.

Other targets for sandstone-type uranium deposits are the Cretaceous and Tertiary red beds along the sub-Andean zone; however here, as in Peru, excessive rainfall may have leached uranium from surface exposures, making it very difficult to detect favorable areas. The same can probably be said for the Paleozoic, Cretaceous and Tertiary red beds close to the Precambrian shield in eastern Bolivia.

The continental ("red-bed") sediments interbedded with the large expanse of marine shales and sandstones of the lower and middle Paleozoic (Cambrian, Ordovician, Silurian and Devonian) are probably less attractive for sandstone-type uranium deposits because they are less likely to contain localized organic remains. On the other hand, they provide a number of geologic settings in which "oxidized facies" rocks are associated or interfinger with "reduced facies" rocks. This would provide ample opportunity for precipitation of dissolved uranium transported through the "oxidized facies" rocks. Particularly attractive would be areas where these geologic settings include uranium-rich granitic intrusives or rhyolitic extrusive rocks which might act as sources for the uranium.

The red-bed sequences mentioned in the preceding paragraphs can be ranked for exploration priority according to the following factors:

1. Association with granitic intrusions or rhyolitic volcanic rocks containing anomalous concentrations of uranium;

2. Association with known oil fields, particularly in the sub-Andean region;

3. Availability of reducing organic matter;

4. Interfingering of oxidized and reduced facies;

5. Optimum sandstone:shale ratios (between 4:1 and 1:1);

6. Regional dip;

7. Evidence for contained acid volcanic tuffs.

Another good target for regional uranium exploration is the large expanse of Precambrian schists in eastern Bolivia. There is a good chance that many of these rocks belong to the early Precambrian and therefore could contain uraniferous conglomerates like the Witwatersrand, Blind River or Jacobina (Mariaca, 1977, p. 9). Unfortunately, the rather heavy rainfall in the area may have leached uranium from the surface, so that the most useful guide to these deposits may turn out to be placer gold deposits (even if only of marginal economic importance in themselves) derived from Precambrian uranium-gold occurrences.

In view of the association of nickel and cobalt minerals with some hydrothermal uranium ores, mines and prospects from which these elements have been reported should be examined. A good example of this relationship in Bolivia is the Sorpresa nickel mine and the Chulchucani cobalt deposit, both containing uranium, which are in a bleached red-bed sequence with oxidized copper minerals. Uranium minerals in Bolivia are also reported in association with tin as at the Llallagua-Catavi tin mine and the Urania tin-tungsten mine. This association may warrant further investigation.

Although no uranium reserves are now credited to Bolivia, the geologic possibilities for several kinds of uranium deposits coupled with the relatively limited work done to date suggest that uranium orebodies will be discovered.

It is estimated that the potential resources of Bolivia are in the range of 10,000 to 100,000 tonnes uranium.

7. BIBLIOGRAPHY

Ahlfeld, Federico, 1954, Los yacimientos minerales de Bolivia. Banco Minero de Bolivia, Corp. Minera de Bolivia, Imprenta Industr. S.A., Bilbao, Spain, 277 pp.

Ahlfeld, Federico, and Schneider-Scherbina, Alejandro, 1964, Los yacimientos minerales y de hidrocarburos de Bolivia. Departamento Nacional de Geología, Vol. No. 5 (Especial), 388 pp.

Mariaca S., Francisco, 1977, Bolivia - Informe sobre: "Uranio: recursos - producción y demanda." Dpto. Materias Primas.

Compiled by USERDA

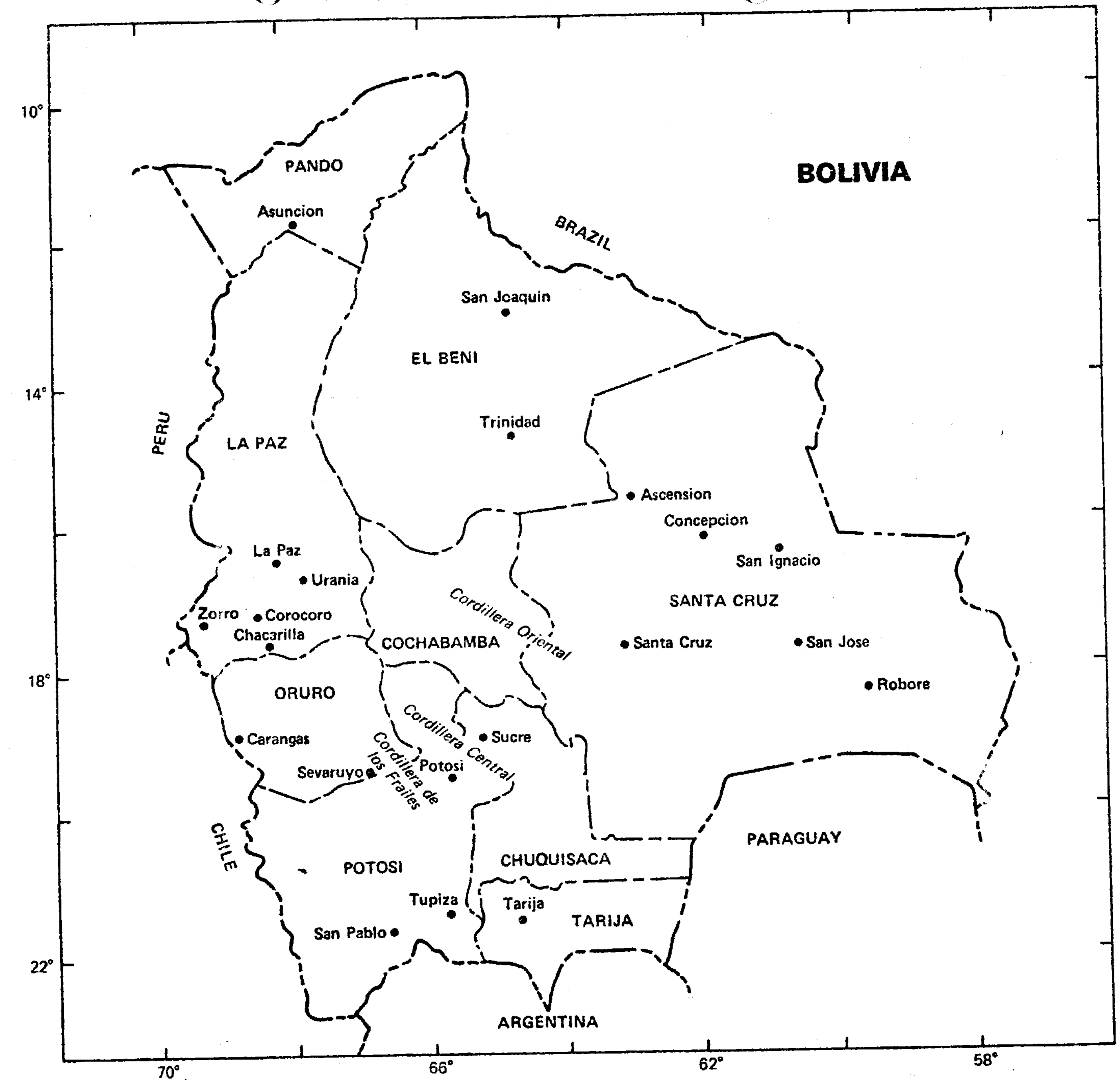
August 1977

TABLE 1

EXPLORATION FOR RADIOACTIVE MINERALS IN BOLIVIA

Year	Airborne Radiometric Surveys sq.kms.	Ground Surveys sq. kms.	Surface Drilling			Total Cost US $
			Meters	Number of holes	Cost US $	
Before 1971		10,000 (1)				200,000
1972		2,000				60,000
73		2,000				70,000
74	15,000	2,000				1,150,000
75	22,800	6,000	431	12	20,000	1,760,000
76	5,547	6,350	10,579	65	1,000,000	1,912,350
77 (projected)	15,000	1,000	7,000	35	450,000	1,400,000
Total	58,344	23,350	18,010	112	1,470,000	6,552,350

(1) General prospecting


BOLIVIA
PANDO
Asuncion
BRAZIL
San Joaquin
EL BENI
Trinidad
PERU
LA PAZ
Ascension
Concepcion
San Ignacio
SANTA CRUZ
La Paz
Urania
Zorro
Corocoro
Chacarilla
COCHABAMBA
Cordillera Oriental
Santa Cruz
San Jose
Robore
ORURO
Carangas
Cordillera Central
Sucre
Cordillera de los Frailes
Sevaruyo
Potosi
CHILE
POTOSI
CHUQUISACA
PARAGUAY
Tupiza
Tarija
TARIJA
San Pablo
ARGENTINA
10°
14°
18°
22°
70°
66°
62°
58°