U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

BIBLIOGRAPHY AND SUMMARY OF DATA AVAILABLE FOR THE SALAR DE UYUNI, BOLIVIA

by

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Open-File Report

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INTRODUCTION

The Salar de Uyuni is one of Bolivia's largest mineral resources. The salar is known to contain significant resources of salt, magnesium, potassium, and boron, as well as one of the world's largest lithium brine deposits. In addition, geological and geophysical data indicate significant potential for gold, copper, and other metal deposits in the volcanic rocks within and surrounding the salar.

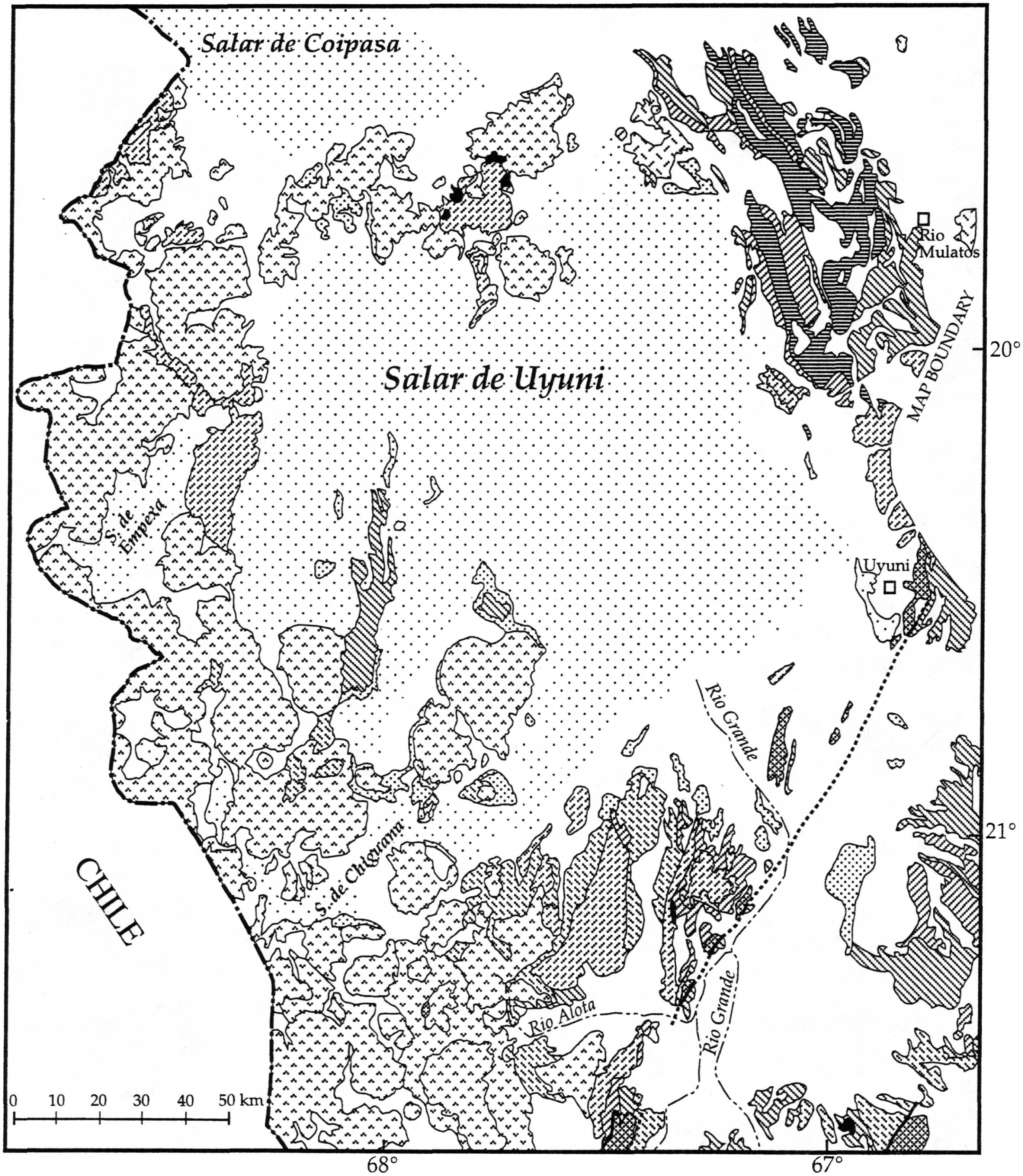
SALAR DE UYUNI

BRIEF DESCRIPTION

Salar de Uyuni (fig. 1) is a wet playa deposit with significant resources/reserves of rock salt (halite) and ulexite, as well as brine containing lithium, potassium, magnesium, and boron. The salar is the remant of lakes that occupied much of the Bolivian Altiplano in the Late Pleistocene. Salar de Uyuni is the largest salt pan (salar) in the world (Erickson and others, 1978) and is one of the world's largest lithium brine resources. In addition, the volcanic rocks underlying and surrounding the salar have created the potential for significant metal resources in the area. The salar occupies an area of over 10,000 sq km at an elevation of 3,653 m. The location of the center of the salar is approximately 20°S and 068°W; topographic/geologic coverage is provided by the Rio Mulato, Uyuni, Salinas de Garci Mendoza, and Villa Martin 1:250,000 quadrangles.

REGIONAL GEOLOGIC ATTRIBUTES

The Salar de Uyuni is located in the Bolivian Altiplano, a large closed basin in the central Andes bordered by the Cordillera Occidental and the Cordillera Oriental and extending from Peru to northern Argentina. The basin has existed since the early Tertiary and was formed during the uplift of the Andes.



Salar de Coipasa
Salar de Uyuni
Rio Mulatos
MAP BOUNDARY
20°
S. de Empexa
Uyuni
Rio Grande
21°
CHILE
S. de Chiguana
Rio Alota
Rio Grande
0 10 20 30 40 50 km
68°
67°

EXPLANATION

- Surficial deposits, undifferentiated (Holocene-Pleistocene)
- Salt deposits (Holocene-Pleistocene)
- Lacustrine deposits (Holocene-Pleistocene)
- Stratovalcano deposits (Holocene-Miocene)
- Ignimbrite (Pleistocene-Pliocene)
- Los Frailes and Morococala ignimbrites (Miocene)
- Intrusive rocks (Pliocene-Oligocene)
- Sedimentary rocks (Pliocene-Oligocene)
- Volcanic rocks, undifferentiated (Miocene and Oligocene)
- Pyroclastic rocks (Miocene and Oligocene)
- Sedimentary rocks (Oligocene-Paleocene)
- Sedimentary rocks (Cretaceous)
- Sedimentary rocks (Paleozoic)

Figure 1. Geology of the Salar de Uyuni area (after Marsh and others, 1992).

LOCAL GEOLOGIC ATTRIBUTES

Host rock(s): Lacustrine sediments and evaporites including extensive clay and mud layers, massive halite (fig. 1).

Associated rock(s): Area is largely surrounded by and in part or wholly underlain by Cenozoic volcanic rocks, largely andesitic in composition. Variable amounts of Pre-Quaternary continental sedimentary and volcano-sedimentary deposits are also present in the drainage area, as well as minor amounts of Pre-Tertiary rocks.

Ore mineralogy: halite, ulexite, brine, sylvite; possibly Cu, Au, Ag.

Gangue mineralogy: gypsum, clays.

Alteration: Strong hydrothermal clay alteration on islands of exposed volcanic rocks of a shallow buried ridge that bisects the salar from north to south.

Structural setting: Closed basin. The salar is bisected by a shallow buried ridge running from the major peninsula on the southern edge to the north shore.

Ore control(s): Arid climate; closed basin; presence of volcanic rocks.

Effect of weathering: Wind erosion may negatively impact surface salt deposits. Water may destroy evaporite deposits.

Climate/Paleoclimate: Remnant shorelines can be found more than 10 m above the present surface. Extensive algal reefs can be found up to 75 m above the present surface. During the Pleistocene, Lago Minchin (26-27,000 years B.P.) and Lago Tauca (12,000 years B.P.) extended more than 100 km north of the present drainage basin of the Salar de Uyuni and included the present drainage systems of the Salar de Poopo and Salar de Coipasa. Salar de Uyuni was the lowest point in the lake's basin. The lake was reduced to approximately is present size about 10,000 years ago. The Pleistocene lake level changes have been correlated with a changing fluid supply from upstream glaciers; i.e., not due to a change in average rainfall values, but to changes in temperature and distribution of precipitation. Today, the salar floods to a depth of about 25 cm during the rainy season and has no surface water during the dry season.

VOLCANISM

Volcanism began in this area in the late Cretaceous or early Tertiary with extrusion of the alkaline Potoco lavas which are of minor extent. Younger volcanism, beginning in the Miocene and continuing today, is of calc-alkaline composition and includes ignimbrites erupted from large calderas and lavas associated with stratovolcanoes. In general, the ignimbrites decrease in age to the west and are thought to be the most likely source of Li and B mineralization. The ignimbrites include parts of the Miocene Upper Quehua Formation in the east, the Miocene Los Frailes Formation in the northeast, and the Pliocene Ignimbrite Formation to the south and west. There are also scattered domal bodies of intrusive-extrusive rhyolite. Composite volcanoes as old as Miocene are known, but most have erupted during the Holocene. The Salar de Uyuni drainage basin contains many thermal springs enriched in Li, B, and other elements that are related to the continuing volcanism.

DRAINAGE BASIN

There is permanent inflow from the Rio Grande de Lipez which drains continental sediments to the southeast of Uyuni and and ignimbrite plateau breached by numerous composite volcanoes to the south. There is seasonal inflow from the Cordillera Occidental, an area largely composed of stratovolcanoes and their associated rocks to the west of the salar. The Rio Grande drains an area of more than 25,000 km^2.

MINERALIZATION

Known mineralization in the Salar de Uyuni includes extensive salt (sodium chloride) deposits, sub-economic to economic brines, and borate mineralization. Salt and ulexite have been produced from the salar. The salt crust covers an area of approximately 10,000 km^2; this crust is very porous, composed largely of halite and gypsum, and up to 10 feet thick. A 121 m deep borehole in 1978 encountered 12 different salt horizons separated by lacustrine sediments. Halite has been produced from the Colchani Mine since the 1500's and reportedly grades 95.10% NaCl. Kunasz (1979) estimated that salt precipitation in the basin began about 350,000 years ago.

There has been historic silver production on the east side of the salar, as well as mining in the Salinas de Garci Mendoza mining district in the north. Recent studies have indicated a potential for epithermal Au systems in the area.

Mines and deposits of the salar area:

Colchani Mine- Holocene halite mine; production since 1500's;
Salmueras del Salar de Uyuni- brine; no production
Salmuera del Rio Grande- brine
Boratera Pampa (Llipi-Llipi)- Holocene ulexite deposits
Salinas de Garci Mendoza District- polymetallic veins
San Cristóbal District- polymetallic veins

PRODUCTION

Salt has been produced since the 1500's.
Ulexite has been intermittently produced from surficial deposits.

RESERVES

Rio Grande delta/Llipi-Llipi area:	12 Mt ulexite (estimate, 1991)
Rio Grande area:	13-14 Mt ulexite ore @ 30% B_2O_3
(Suarez and others, 1993)	
Salar de Uyuni brine:	3.2 Mt B @ 247 g/l
(Crozier, 1986)	5.5 Mt Li @ 423 g/l
	110 Mt K @ 8.7 g/l
(Ballivian and Risacher, 1981)	64,000,000,000 mt salt, potential resource
Salmueras del Rio Grande (Ballivian and Risacher, 1981)	600,000 mt Li, 4,500,000 mt K, 390,000 mt B; potential brine resource

ECONOMIC LIMITATIONS

Physical/chemical properties affecting end use: The Mg to Li ratio is 21.5 and Mg precipitated with Li during trial processing.

Distance limitations to transportation, processing, end use: Railroad junction at town of Uyuni

SOURCES OF INFORMATION

In this section, references are catagorized by topic.

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CENOZOIC VOLCANISM

Avila-Salinas (1991); Baker and Francis (1978); De Silva (1989); Goemans and others (1987); Kussmaul and others (1977)

PALEOCLIMATE/CLIMATE

Johnson (1976); Seltzer (1990); Servant and Fontes (1978); Vacher and others (1988)

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