



Brine grades in Andean salars: When basin size matters A review of the Lithium Triangle

Romina Lucrecia López Steinmetz, Stefano Salvi

► To cite this version:

Romina Lucrecia López Steinmetz, Stefano Salvi. Brine grades in Andean salars: When basin size matters A review of the Lithium Triangle. *Earth-Science Reviews*, 2021, 217, pp.103615. 10.1016/j.earscirev.2021.103615 . hal-03204125

HAL Id: hal-03204125

<https://hal.science/hal-03204125>

Submitted on 21 Apr 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Journal Pre-proof

Brine grades in Andean salars: When basin size matters A review of the Lithium Triangle

Romina Lucrecia López Steinmetz, Stefano Salvi

PII: S0012-8252(21)00115-X

DOI: <https://doi.org/10.1016/j.earscirev.2021.103615>

Reference: EARTH 103615

To appear in: *Earth-Science Reviews*

Received date: 16 May 2020

Revised date: 9 February 2021

Accepted date: 27 March 2021

Please cite this article as: R.L.L. Steinmetz and S. Salvi, Brine grades in Andean salars: When basin size matters A review of the Lithium Triangle, *Earth-Science Reviews* (2021), <https://doi.org/10.1016/j.earscirev.2021.103615>

This is a PDF file of an article that has undergone enhancements after acceptance, such as the addition of a cover page and metadata, and formatting for readability, but it is not yet the definitive version of record. This version will undergo additional copyediting, typesetting and review before it is published in its final form, but we are providing this version to give early visibility of the article. Please note that, during the production process, errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

© 2021 Published by Elsevier B.V.



Brine grades in Andean salars: when basin size matters A review of the Lithium**Triangle**

Romina Lucrecia López Steinmetz^{1,*} lucrecialopezsteinmetz@hotmail.com, Stefano Salvi²
stefano.salvi@get.omp.eu

¹IDEVEA (CONICET - UTN), Av. GRAL. J.J. Urquiza 314, 5600 San Rafael, Mendoza, Argentina

²University of Toulouse, CNRS, GET, IRD, OMP, 14 Av. Edouard Belin, Toulouse 31400, France

*Corresponding author

Abstract

The Lithium Triangle, a zone of the Central Andes characterized by the presence of lithium (Li)-rich salt pans within endorheic basins, has gained a worldwide reputation chiefly due to its exceptional Li brine-type deposits. We summarize scientific hydrochemical reports, totalizing a data set composed of 477 brine samples across the Lithium Triangle. Brine compositions are predominantly of the $\text{Cl}^- - \text{SO}_4^{2-} / \text{Na}^+ - \text{Mg}^{2+}$ type, however, major brine chemistry and Li^+ grades vary across the Andean plateau. Brine compositions show some degree of geographic organization but no clear pattern was observed in the Li^+ distribution across the plateau. We highlight an interdependency between the areal surfaces of salt pans and endorheic basins, which, related to Li concentrations, show the following linear proportions: 1) a 1:5 to 1:10 proportionality between the surfaces of basin catchments and those of salt pans; 2) a 2:1 proportionality between maximum and mean Li values; the latter implies that the equation $\text{mean Li} \approx \frac{1}{2} \text{max Li}$ can be employed to predict indicative mean

grades during Li surveys in the Central Andes. In addition, the concentrations of Li can be addressed with respect to the area of salt pans and/or its basin catchments: it would be not only the largest, but also the oldest salars that are expected to hold the greatest Li concentrations. Finally, the area involving all salt pans in the Andean plateau is more than three times the size of what is known as the Lithium Triangle and has a curved crescent shape; we thus propose referring to it in the future as the Lithium Crescent.

Keywords: salt pan; endorheic basin; hydrochemistry; Andes

1. Introduction and historical background

The demand for lithium (Li) has recently known a great increase worldwide due to its application in the fabrication of rechargeable batteries (for mobile phones, personal computers, electric vehicles, etc.). Known global lithium resources involve about 31 Mt, which would represent ~1.50 times the global estimated demand up to the year 2100 (Kesler et al., 2012). Nowadays, lithium is mostly obtained from pegmatite- and brine-type deposits. The former consist of conventional Li mining and represent ~4 Mt (~13%) of estimated resources. Apart from an additional 5 to 6 Mt potential production from hydrothermal solutions and oilfields (Kesler et al., 2012), the remaining ~2/3 (~68%) of global lithium resources are contained in brine-type deposits. This makes them indispensable to meet the growing demand and has caused Li-rich salars to attain the status of an economically, technologically and geopolitically strategic resource (Garrett, 2004; Gruber and Medina, 2010; Mohr et al., 2010; Houston et al., 2011; Kesler et al., 2012; López Steinmetz and Fong, 2019).

Li is a relatively abundant element on Earth with a concentration in the upper continental crust of about 35 ± 11 ppm (Teng et al., 2004). As Li is a very reactive and

geochemical incompatible element, it is commonly present in natural waters as a solute, in its ionic form, Li^+ . The mean Li concentration in sea water is 0.18 mg L^{-1} (Riley and Tongudai, 1964), whereas continental waters are characterized by highly variable Li values. Salt pans (salars or salt flats, desert areas where salts accumulate) in arid regions of the globe store brines that contain Li concentrations often averaging two to three orders of magnitude above those in sea water. Most brine-type deposits involve concentrations of more than 400 mg L^{-1} of Li.

The Andean plateau in South America, one of the most peculiar geological features on Earth, has gained a worldwide reputation due to its exceptional Li brine-type deposits (Kesler et al., 2012). The constraints imposed by environmental challenges and the need for strong technological developments to replace fossil fuels are global factors that have driven the Andean Li rush during now more than a decade. Under the effect of the lithium rush, the plateau region became known as “The Lithium Triangle”. This was an informal appellation originally designating the area comprised between the Salar de Atacama in Chile (#12 in Fig. 1), the principal Li mine in the world (Moraga et al., 1974; Ide and Kunasz, 1989; Kunasz, 2006), the Salar de Uyuni (#3) in Bolivia to the north (Ericksen and Salas, 1987; Risacher and Fritz, 1991), and the Salar de Hombre Muerto (#43) in Argentina to the south (Godfrey et al., 2013) (Fig. 1). This delimitation of the Andean Lithium Triangle then became established based on the relevance of these three salars, which have been the most important Li spots during the last years. However, there are several more Li-bearing salt pans in this Andean region, many of which located outside of this triangle (Fig. 1). In addition, the nonscientific literature (i.e., diverse press articles, NI reports of mining prospects, etc.) commonly considers all the Andean salt flats as containing significant amounts of Li, although data on brine hydrochemistry, including Li grades, are still quite limited, to this date. Therefore, we consider it is important to delimit the area containing all known salt pans. As shown in Figure

1b, such region (in green) corresponds to a curved crescent shape of more than three times the size of the Triangle (in pink), to which we propose referring to as the Lithium Crescent.

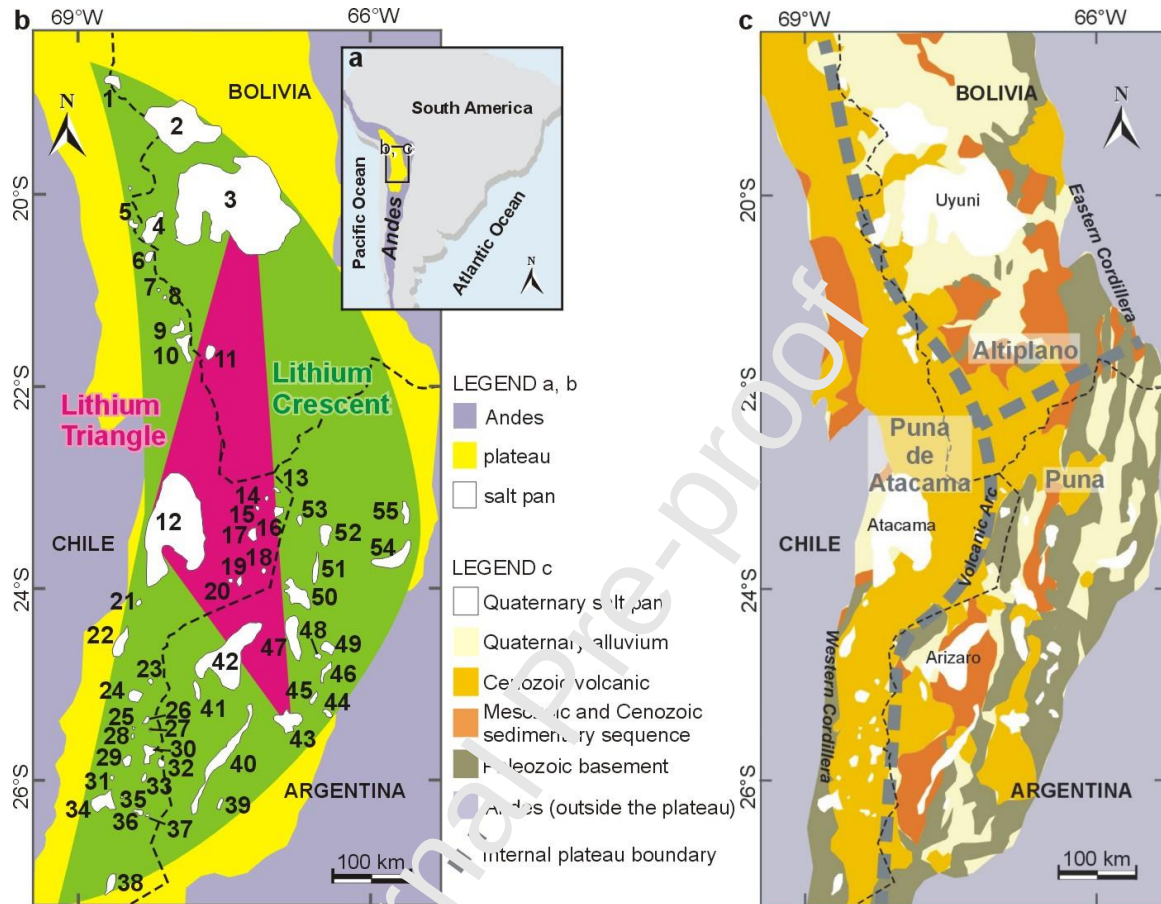


Figure 1. Simplified maps showing the location of a) the Andean plateau and b) salt pans, the Lithium Triangle (pink), and proposed Lithium Crescent (green) corresponding to the area involving all salt pans on the plateau. c) Simplified lithological map of the Andean plateau (modified from Allmendinger et al., 1997), showing the location of the Puna, Puna de Atacama and Altiplano. Dashed black lines represent national borders. Salt pans are numbered in panel b as in Table 1.

The interest for Andean salt pans and their resources began almost a century ago. The first studies were conducted across the Puna de Atacama in northern Chile by geoscientists of the USGS (United States Geological Survey). To this early period of hydrological and geochemical surveys correspond the reports made by Clark (1924), Ericksen (1961, 1963), and Dingman (1967). A few years later, during the 70's, lithium was already perceived as an important resource, as reveals the book "Lithium Resources and Requirement by the year

2000” edited in 1976 by James Vine (also of the USGS). Some of the chapters in this book have become milestone contributions on the topic (e.g., Ericksen et al., 1976b; Kunasz, 1976). During this period, the Chilean State started having an active role on the geological surveying of the Puna de Atacama (the Chilean and western part of the Andean plateau), and on the study of the hydrochemistry of the Salar de Atacama (Moraga et al., 1974; Vila, 1975). Exploration of Andean salars and their Li resources formally began in 1975, when the Chilean State, in association with private companies, conducted the first formal survey of the Salar de Atacama (Kunasz, 1976). Simultaneously, the USGS announced the first results of analyses on two brines samples from the Salar de Uyuni, revealing Li concentrations as high as 490 and 1,510 mg L⁻¹ (Ericksen et al., 1976a, 1976b). Since those times, Atacama and Uyuni founded the biggest expectations on the emerging interest in Li-brine type deposits (Mardones, 1986).

The role of the USGS in generating the fundamental knowledge on the hydrochemistry of Andean salt pans, especially in the Puna de Atacama but also in the Bolivian Altiplano (see Ericksen et al., 1977), remained predominant for more than half a century and continued up to the end of the 80’s (see Stoertz and Ericksen, 1974; Ericksen and Salas, 1977; Ericksen et al., 1978; Ericksen and Salas, 1987; Ide and Kunasz, 1989). The two following decades were characterized by the acquisition of vast hydrochemical data sets of many Chilean salars (Alonso and Risacher, 1996; Risacher and Alonso, 1996; Risacher et al., 2003) and Uyuni (Risacher and Fritz, 1991; Risacher and Fritz, 2000; Risacher and Frits, 2009; Lowenstein and Risacher, 2009). These new major contributions, which included for example the hydrochemical characterization of more than 170 brine samples across the entire Uyuni (Risacher and Fritz, 1991), were in charge of a French-Chilean council headed by Professors François Risacher of the IRD (Institut de Recherche pour le Développement, France) and Hugo Alonso of the UCN (Universidad Católica del Norte, Chile). From this French-Chilean

collaboration emerged the hydrochemical data available today on the Puna de Atacama and Altiplano salt pans, and which remain currently used by COCHILCO (Corporation Chilena del Cobre, the Chilean public society owning mining properties for Cu, Li and other metals in Chile). Additional hydrological and hydrochemical studies, including isotopic assessments in salars and hydrothermal springs in the Puna de Atacama and Altiplano, have been conducted during the last years (e.g., Carmona et al., 2000; Boschetti et al., 2007; Vasquez et al., 2013; Boutt et al., 2016; among others). It was only concurrently to these recent studies that the lithium prospection started along the southeastern side of the Central Andes.

Salars in the Puna (i.e., the Argentine portion of the Andean plateau) have received much less attention than those in the Puna de Atacama and Altiplano. It was probably due to the major attraction caused by the enormous Li resources that stores Atacama (with exceptional Li mean concentrations of $1,400 \text{ mg L}^{-1}$; Moraga et al., 1974; Ide and Kunasz, 1989; Kunasz, 2006), and perhaps also due to the blinding expectations triggered by a salt pan having such a giant dimension as Uyuni ($10,580 \text{ km}^2$). It remains that the Puna salt pans stayed almost unexplored up to only a decade ago, despite the recent context of the Andean lithium rush. The first hydrochemical studies were conducted locally on a few salars: the Salar del Rincón (#50; Ovejero Toledo et al., 2009), Salar de Hombre Muerto (Godfrey et al., 2013), Olaroz (#52; Llorca et al., 2016; Franco et al., 2016), Guayatayoc (#55; López Steinmetz, 2017), and the first isotopic data on the Salar de Ratones (#45), Centenario (#46), and Olaroz (Orberger et al., 2015; García et al., 2019; Franco et al., 2020). A broad survey of the Li-bearing salars in the Puna plateau was only recently accomplished, by geoscientist of the Argentine State, who investigated the brine hydrochemistry for the 17 major salars of this part of the Central Andes (López Steinmetz et al., 2018; López Steinmetz et al., 2020a). Because of this long-lasting lack of information, so far it has not been possible to address the hydrochemistry of Andean salt pans in a regional perspective, i.e., in a spatial-geographical

sense, which implies having an overview of all of these salt pans together. Almost a century after the first USGS surveys, the last surveying achievements in the Puna salars finally give us the opportunity of compiling the existing data set and globally assess the hydrochemistry of the Lithium Crescent.

Li-bearing Andean salt pans are exclusively hosted in endorheic basins (isolated hydrological units corresponding to internally drained areas). The onset of endorheism in the Andean plateau established in the Neogene, associated with the creation of orographic deserts within intermontane settings in response to plateau uplift, as well as widespread volcanism (Alonso et al., 1991; Vandervoort et al., 1995; Alonso et al., 2006; López Steinmetz et al., 2020b). The formation of endorheic basins and salt pans is a function of the spatial and temporal distribution of the topographic configuration, sedimentation and erosional processes, as well as climate (Sobel et al., 2003; Hilley and Strecker, 2005; García-Castellanos, 2006; Garreaud, 2009; Tremblay et al., 2015; López Steinmetz et al., 2020b). One might suspect that, under analogous climatic and geological conditions, whichever they may have been, the larger a basin catchment, the larger the size (and volume; i.e. depth) of the salt pan. But because Earth and its processes are typically multi-dimensionally (4D, space - time), heterogeneous and complex (Becker and Braun, 1999; Paola et al., 2009), this relationship cannot be taken for granted. One of the objectives of the present contribution is to address the interdependency between the areal surfaces (size) of salt pans and of their endorheic basins and relate them to Li grades within an Andean perspective. Remarkably, our findings indicate that this size function follows in fact a proportional ratio across the Andean plateau.

No clear geographical pattern in Li distribution (nor concentration) has been found across the Lithium Crescent (López Steinmetz et al., 2020a), except that maximum Li concentrations have been reported from salt pans located in the center of the plateau (Fig. 1). Similarly, consistently with the latest studies on this area (Egenhoff and Lucassen, 2003;

Peralta Arnold et al. 2017; García et al., 2019; Meixner et al., 2019), our observations rule out a geographical control on the primary source of Li (and its concentration), and suggest that a combination of basin-scale processes and endorheic surface sizes control, at least in part, Li grades. It is likely that the lithological characteristics of each salar will have contributed to its geochemical composition. However, to our knowledge, no such study has been carried out yet. Figure 1c shows a synthetic view of lithologies underlying salt pans in the Andean plateau. Any given salar sits on several units, which influence the specific input of the lithology on a salar's chemical signature that are in also probably controlled by more large basin-scale processes like hydrothermalism.

In addition to the salar/basin size function, further objectives of the present contribution are: - to summarize the hydrochemical data sets of brines from salt pans at the Andean scale; - to identify regional patterns (i.e., spatial-geographical) for Li distribution and brine concentrations; - to recognize useful criteria (e.g., hydrochemical, geographical, geomorphological, etc.) for surveying of Li-brine type deposits; - to discuss in absolute and comparative terms the relevance and potential of Andean prospects. A better knowledge of the salars in this region of the Andes and of their Li endowment will necessarily prove beneficial for a better governance of natural resources, whether it be administrative exercise, private sector investment strategies, or simply contributing to the public knowledge.

2. Geology of the Andean Plateau

The Andes display along the western South America (Fig. 1). The Orogenic processes that conducted to the Andes mountain building started in the early Cenozoic after major reorganization of tectonic plates in the eastern Pacific, driving the convergence of the Nazca and South American plates (Tassara, 2005, and references therein).

The Andean plateau (Fig. 1 B) is a tectonic elevation area settled in the Central Andean zone. It occupies parts of northern Chile and Argentina, western Bolivia and southernmost Peru. The plateau involves the internally drained basins of the Central Andes (Allmendinger et al., 1997), which largely correspond to the areas settled above the 3 km elevation contour (Isacks, 1988).

The plateau involves a >60-70 km-thick crust and thin lithosphere (without or with very thin lithospheric mantle, see Allmendinger et al., 1983; Coira et al., 1993; Allmendinger and Gubbels, 1996; Whitman et al., 1996). The plateau is flanked to east and west by morphotectonic units of the continental plate, the Eastern and Western Cordilleras (Fig. 1 C), whereas in the N-S direction the plateau extent coincides with abrupt dip changes along the subduction zone, from flat ($<10^\circ$) to normal ($\sim 30^\circ$) subduction, and with the intersection of the Nazca and Juan Fernández oceanic ridges (Cassara, 2005, and references therein). The Eastern Cordillera reaches 5-6 km elevation and it is a doubly-vergent deformation belt active until the middle-late Miocene (Heraud et al., 1996; McQuarrie, 2002). South of 27°S , the tectonic style of the Eastern Cordillera transitions to uplifted basement blocks made of crystalline Palaeozoic rocks and the Sierras Pampeanas (Ramos et al., 2002). The Western Cordillera is an Eocene magmatic and tectonic belt (Mpodozis and Ramos, 1989) that is related to a west-vergent thrust system (WTS, Muñoz and Charrier, 1996). The Western Cordillera has peaks that rise to ~ 6 Km-in-high and involves stratovolcanoes of Miocene and younger age at the margin of the plateau (Jordan et al., 2010).

The geological characteristics of the Andean plateau vary along-strike. Internal plateau changes on topography, volcanism, tectonic style and subduction conditions, among others relevant aspects, have led to identify major internal plateau subdivisions: the Altiplano (15° - 22°S), the Puna (22° - 27°S) and the Puna de Atacama (east of the volcanic arc) (Jordan et al. 1983, Mpodozis and Ramos, 1989; Fig. 1 C). The Puna - Altiplano transition occurs at $\sim 22^\circ\text{S}$.

The Altiplano is characterized by a broad, low-relief, with a mean elevation of ~ 3.8 km. The Puna lies at an average elevation nearly a kilometer higher than the Altiplano, holds younger mafic magmatism (Maro et al., 2017), and its physiography involves several endorheic depressions bounded by basement-cored ranges (Whitman et al., 1996, Allmendinger et al., 1997, Jordan et al., 2010). The volcanic arc displays nearby N-S and separates the Altiplano-Puna on the eastern side of the plateau from the Puna de Atacama in the west. The volcanic arc (also known as the CVZ, the acronym for Central Volcanic Zone, 15° - 28° S) is a chain of Miocene to Quaternary stratovolcanic complexes and andesitic rhyodacitic domes of high-K calcalkaline affinities (Allmendinger et al., 1997; Kay et al., 1999, Jordan et al., 2010). The Puna de Atacama sets west of this volcanic arc and involves the Atacama basin, a major topographic and geologic anomaly that is one of several anomalous features occurring across the plateau margin at this latitude (Schurr et al., 1999; Götze and Krause, 2002; Belmonte, 2002).

From a stratigraphic point of view, the plateau is filled with synorogenic deposits that record clastic, volcanic, and evaporative Cenozoic episodes (Allmendinger et al., 1997; Baby et al., 1997; McQuarrie, 2002, Alonso et al., 2006). Most of compressive deformation and plateau uplift occurred in the Miocene and Pliocene all together with major felsic magmatism in the region. Large volumes of dacitic ignimbrites (over 104 km^3 erupted volume) erupted from caldera complexes located in and to the east of the arc conducted to Altiplano-Puna plateau to be the largest Neogene ignimbrite province in the world (Babeyko et al., 2002, and references therein).

The plateau basement largely consist of Ordovician, and, locally, older metasedimentary marine, plutonic and volcanic rocks. Basement rocks dominate the outcrop along uplifted ranges. The basement is unconformable overlain by sparse exposures of marine calcareous sequences that record the Cretaceous - Paleocene rift basins. These deposits

correspond to the Salta Group (Brackebusch, 1883, 1891; nom. transl. Turner, 1959) in the Puna and its northwards equivalent Supersequences Puca and Coro-Coro (Sempere et al., 1997) in the Plateau and Western Cordillera of the Bolivian Andes.

Diachronic deformation (Hongn et al., 2007) drove Andean deposition in emergent continental basins. Cenozoic basin fill typically involves red beds, conglomerates and playa deposits containing interlayered evaporites and tuffs. Andean sequences resulted from sedimentation in interconnected and isolated basins during the evolving Andean foreland system (Lopez Steinmetz and Montero-Lopez, 2019, Montero-Lopez et al., 2020, Adad et al., 2020, and references therein). Regional isolation has strengthened once the plateau raised in the Mio-Pliocene. This period was characterized by a flare-up magmatism, regional uplift and the establishment of generalized endorheism (Isacks, 1988; Kay et al., 1994, Allmendinger et al., 1997; Garzzone et al., 2008, 2017, Gianni et al., 2020). The plateau rise and the Andean basin formation remain subjects of ongoing debate, as some data seems indicate that the formation of the high plateau, endorheism and intermontane basins could have started together and as early as the Paleogene (Canavan et al., 2014; Scott et al., 2018, López Steinmetz et al., 2020c). Quaternary alluvium covers the low-laying planes between mountain ranges and volcanoes. Halite-dominated pans, locally known as *salaes* and *salinas*, formed because of the extremely arid climatic conditions that prevail in these high-altitude endorheic basins since at least the Miocene (Alonso et al., 2006).

3. Material and Methods

The dataset in this article comprises two types of information: 1) major hydrochemistry including Li concentrations in brines from Andean salt pans, and 2) the areal surface (size) of these salt pans and of their basin catchments. The hydrochemical and Li data were obtained by compiling available information for 49 Andean salt pans published in the

scientific literature. All the areal surfaces of salt pan and respective basin catchments were obtained from satellite imagery. These values consist of geomorphological considerations of areal surfaces for 55 salt pans and their basin catchments, which include the 49 salt pans for which Li data were obtained, plus 6 additional salt pans from which there is no available hydrochemical information (i.e., Salar Grande, Capur, Los Infieles, Salar de la Laguna, La Piedra Parada, and Wheelwright). Surface sizes are summarized in Table 1. Salt pan locations are shown in Figure 1 and detailed in Table A1 of the Electronic Supplementary Data.

As detailed in the historical context outlined in Section 1, it is important to realize that the survey of Andean Li has involved a long period of data acquisition and that the available brine chemistry dataset emerged from diachronic sampling campaigns conducted by various scientists during different periods: 1) in most cases, the brine dataset from a particular salt pan results from a unique sampling campaign (i.e., no longitudinal sampling variation data are available), and 2) from a regional point of view (i.e., Andean plateau scale), when comparing the brine chemistry of different salt pan datasets are composed by diachronic sampling from one salt pan to the other. These aspects imply disparate frameworks for time-dependent conditions that can influence the sampling and analytical methodology. Examples include climate (which controls saline saturation of brines regulating Li concentrations), sampling techniques (which determine the quality and representativeness of sampled brines), advances in analytical methodologies (which define hydrochemical data quality), etc. Therefore, we made sure to be particularly careful when assessing the validity of each dataset included in our regional brine hydrochemistry compilation: we only considered peer-reviewed scientific articles to construct our dataset.

The hydrochemical data compiled in this review (Table 2) correspond exclusively to residual brines from salt pans. Care was taken to exclude values from springs, rivers or streams from the dataset. In most cases, samples correspond to shallow and sub-surface brines

that were collected from hand-dug pits in the salt pans, i.e., at depths less than 1 m. In a few cases, samples were taken directly from brine pools (i.e., ponding brines) that had formed naturally in the salars (Risacher et al., 1999; Lopez Steinmetz et al., 2018; 2020). Data considered for the Uyuni and Coipasa salars, in addition to near-surface brines, consists also of a collection of samples obtained at depths of up to 10 m from 40 holes dug in the salt crust of these salars. In Table 2, the sampling depths (in centimeters) are indicated by numbers in names of the 176 samples from Uyuni and Coipasa (for more details see Risacher and Fritz, 1991). Due to the regional scale of this review and, as just mentioned, the fact that most considered brines come from sampling within the salt pans, the specific location and depth of each of the 477 brines constituting our dataset (Table 2) are not reported here. In Table 2 all samples are grouped by salt pans which are located in Figure 1 and whose coordinates are provided in Table A1 of the Electronic Supplementary Data. In the following lines of this section, all references are provided to the scientific literature considered, as well as details on criteria for building the dataset. For further information on the sampling and analytical techniques deployed for specific data, or the specific location of each sample, the reader is referred to the original papers from where the datasets were taken.

In this review, salt pans are grouped into Altiplano, Puna de Atacama and Puna salars, which is roughly equivalent to say Bolivian, Chilean and Argentinian, respectively, given that national borders follow natural boundaries in the plateau (Fig. 1). Readers that are not familiar with Andean geography, can find more detailed discussion on Andean salt pans and brine chemistry in the references listed in the following paragraphs.

The hydrochemical data set (Table 2) involves 477 brines samples and is composed of:

- 178 brine samples from the Altiplano salt pans that majorly correspond to data published by Risacher and Fritz (1991), and to a minor extent by Ericksen and Salas (1987),

- 126 brine samples from the Puna salt pans (Ericksen and Salas, 1987; López Steinmetz, 2017; López Steinmetz et al., 2018; García et al., 2019; López Steinmetz et al., 2020a), and
- 173 brine samples from the Puna de Atacama salt pans reported by Moraga et al. (1974), Vila (1975), Ericksen and Salas (1987), and Risacher et al. (1999; summarized by COCHILCO, 2013).

For the case of the Salar de Atacama, we used samples ATA₀ and ATA_{do}, ATA, and Do1 to Do5 reported for Moraga et al. (1974) and Ericksen and Salas (1987), and ATA-05 and ATA-22 reported by Risacher et al. (1999), which are - to the best of our knowledge - the only available published data on brine samples collected within this salt pan, and offering a complete spectrum of major ions, Li, and TDS. It is important to note that Li values that are either i) isolated, from incomplete ionic characterizations, or ii) from non-scientific reports, were not taken into consideration. According to these criteria, the considered Li values are the unique, scientific published data of brine samples available from samples collected in the Andean salt pans, and offer a complete hydrochemical spectrum. Data reported in other scientific works correspond to inflow waters and/or hydrothermal springs, and not to residual brines lying within these salt pans, and/or do not offer a complete spectrum including TDS, major ions, and Li (i.e., Ericksen et al., 1976a, 1976 b; Crespo et al., 1987; Rettig et al., 1987; Scandiffio and Alvarez, 1990; Scandiffio and Rodriguez, 1990; Mardones and Chong, 1991; Bevacqua, 1992; Garcés et al., 1996; López et al., 1996; Carmona et al., 2000; López Julián et al., 2001; Risacher et al., 2002; Banks et al., 2004; Vinante and Alonso, 2006; Boschetti et al., 2007; Ovejero Toledo et al., 2009; Salas et al., 2009; Schmidt, 2010; An et al., 2012; Durán Iriza, 2012; Vásquez et al., 2013; Boutt et al., 2016; Corenthal et al., 2016; Munk et al., 2018; Godfrey and Alvarez-Amado, 2020).

Mean brine compositions were computed from the information available, summarized in Table 3. In the case of the Salar de Atacama, we also considered values of 1,400 and 6,400

mg L⁻¹ as the representative mean and maximum Li concentrations of the Atacama brines, respectively, as listed in Moraga et al. (1974; see also Ide and Kunasz, 1989; Kunasz, 2006). Accordingly, the hydrochemical and Li⁺ concentrations of the Atacama brines (i.e., mean and maximum of 562 and 1,570 mg L⁻¹, respectively) from Moraga et al. (1974), Ericksen and Salas (1987), and Risacher et al. (1999) are used for general characterizations such as shown in Figures 2 to 6, however, we used the 1,400 and 6,400 mg L⁻¹ mean and maximum Li concentrations when assessing this major salar in its regional context (Figs. 9 and 10). Li maximum (*max*) and mean concentrations of Li⁺ and Mg²⁺ in all salars (Table 4) are also considered and discussed. Saturation indexes (SI) at standard ambient temperature and pressure (SATP, 25°C, 1 atm) were computed using the Phreeqc 3.6.2 software, to address the saturation state of brines with respect to main salts. The most representative ranges of SI values are reported in the Results section.

4. Brine hydrochemistry across the Lithium Crescent

4.1. Altiplano salars

A few salt pans occur in the southern Bolivian Altiplano. Amongst these salars, the most prominent are Uyuni and Coipasa (#2): with an area of 10,000 km², Uyuni is by far the largest salt pan on Earth, and with its 1,650 km² Coipasa is the fourth largest salar in the Andean plateau (Fig. 1, Table 1). Empexa (#4 in Fig. 1) and Pastos Grandes (#11) also are large salars with their 402 and 124 km², respectively. These salt pans are located at altitudes >3.60 km asl, and their catchments involve endorheic basins having disparate surfaces that range between 600 and 45,200 km² (Table 1). None of these salt pans is yet being mined for lithium.

The brine chemistry of Uyuni and Coipasa was thoroughly described by Risacher and Fritz (1991), whereas only two isolated samples are available from Empexa and Pastos Grandes (Ericksen and Salas, 1987; Table 2). The Altiplano salt pans contain highly saline brines with mean TDS (Total Dissolved Solids) values comprised between 123 and 321 g L⁻¹ (Table 3), although in most cases TDS are in a range from 100 to ~220 g L⁻¹ (Risacher and Fritz, 1991; Table 2). The maximum TDS values reported are of 351 g L⁻¹ and 368 g L⁻¹, respectively from Uyuni and Coipasa (Ericksen and Salas, 1987).

Based on their major chemical compositions, brines in Uyuni are of the Mg²⁺ - Na⁺ / Cl⁻ - SO₄²⁻ type, with Mg²⁺ ≥ Na⁺, whereas in Coipasa, Empexa and Pastos Grandes brines are of the Na⁺ - Mg²⁺ / Cl⁻ - SO₄²⁻ type, with Na⁺ > Mg²⁺ (Fig. 2 and 3 a). Main characteristics of brines from Altiplano salars are their high Mg²⁺ concentrations and their relatively low K⁺ and Ca²⁺. Stoichiometric ionic ratios between Na⁺ and Cl⁻ are consistent with the equilibrium solubility of halite for a certain number of the Uyuni brines (i.e., SI ≈ 0, e.g., samples RA130, RB180, RC120), however, a large number of them plot along an oblique line with respect to the 1:1 proportion (Fig. 3 b), suggesting that the brine reached saturation with respect to (and thus precipitated) halite (SI > 0 and up to 0.36, e.g., samples RX10, RZ1, CA150). Except for some samples from Coipasa (e.g., CB150 and CA250), the fact that the SO₄²⁻ : Mg²⁺ ratio forms a trend Mg²⁺ > SO₄²⁻ perpendicular to the 1:1 line, is in turn consistent with the saturation of the brines with respect to epsomite (MgSO₄ · 7H₂O, SI > 0 and up to 0.73, e.g., samples RZ1, RT15, RX10), and/or other Mg-bearing sulfated salts (Fig. 3 c).

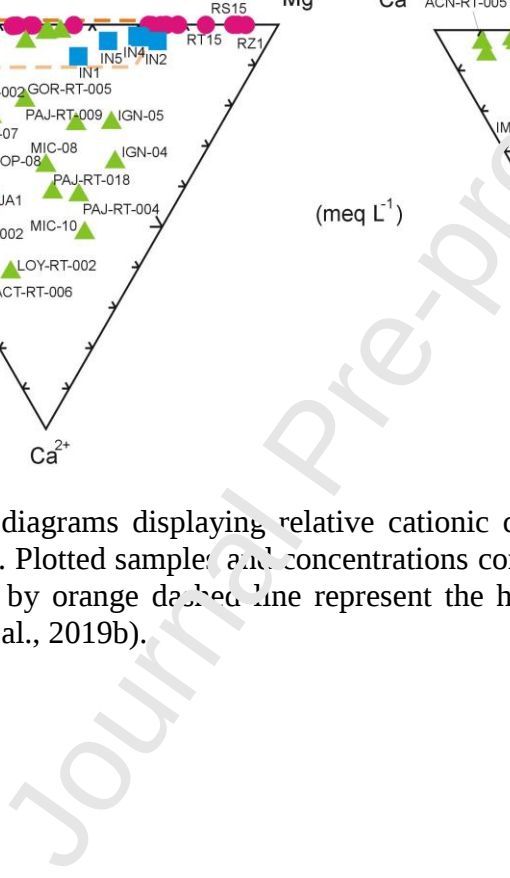


Figure 2. Ternary diagrams displaying relative cationic concentrations measured in brines from Andean salars. Plotted samples and concentrations correspond to those detailed in Table 2. Fields delimited by orange dashed line represent the hydrochemistry of brines from the Tibet Plateau (Li et al., 2019b).

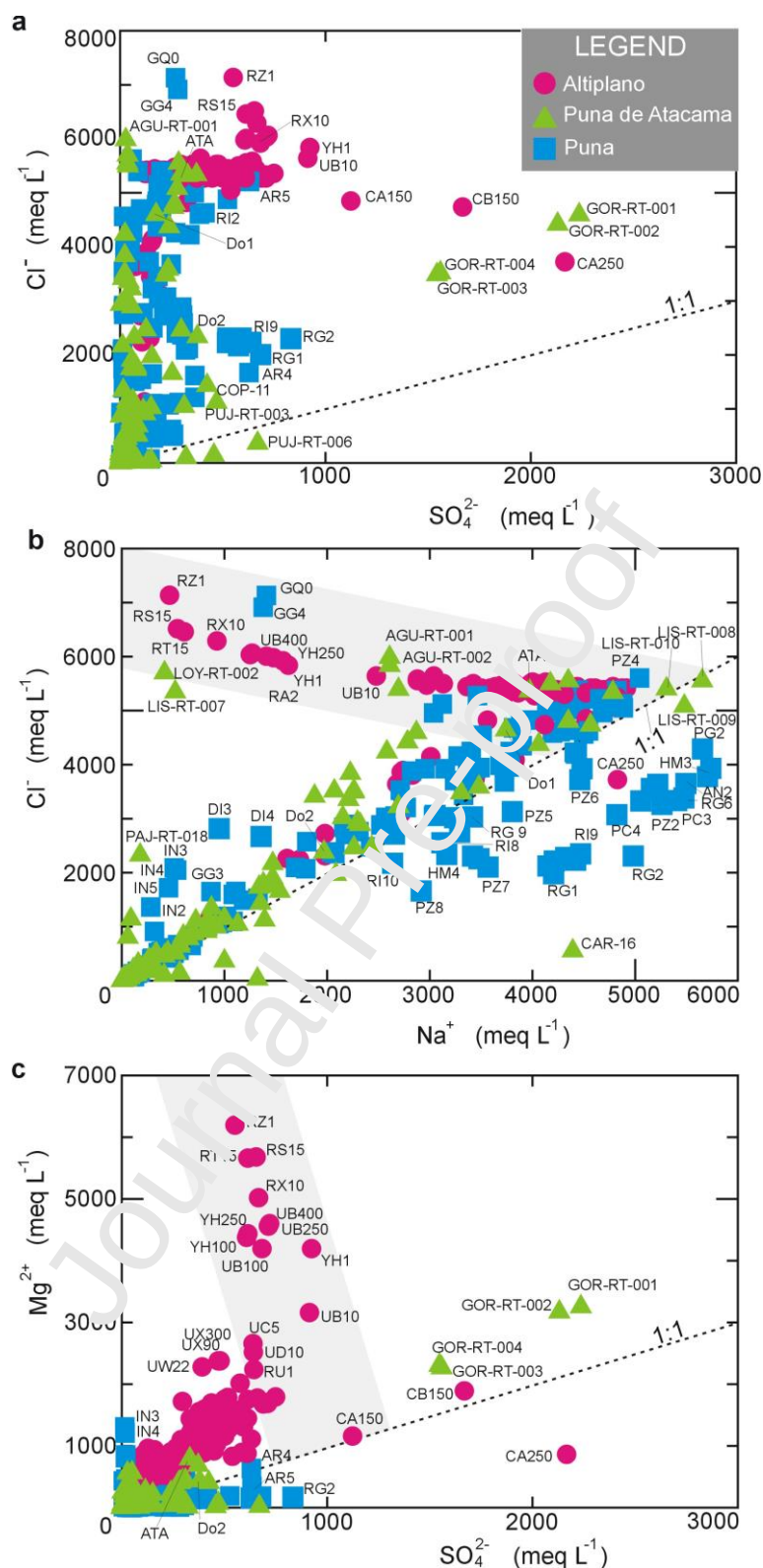


Figure 3. Scatter diagrams plotting the concentrations of a) SO_4^{2-} versus Cl^- , b) Na^+ versus Cl^- , and c) SO_4^{2-} versus Mg^{2+} in brines from Andean salars. Gray zones in panels a) and b) signal trends that are independent from the 1:1 ratio (dashed line) and that could correspond to brine saturation. Plotted values correspond to concentrations detailed in Table 2.

The mean Li^+ concentrations in Empexa and Coipasa are 213 and 258 mg L^{-1} , respectively, whereas the only available sample from Pastos Grandes indicates Li values as high as 1,640 mg L^{-1} (Ericksen and Salas, 1987). In Uyuni the maximum reported Li value is of 4,720 mg L^{-1} with a mean of 715 mg L^{-1} (Risacher and Fritz, 1991; Tables 2 and 3). Two different tendencies are observed between the concentrations of Li^+ and Cl^- in the Altiplano brines: an oblique trend, which only includes a part of the Uyuni's brines, suggests a positive correlation between Li^+ and Cl^- , whereas a horizontal trend including samples at higher Li values, shows that the concentrations of Li^+ in most samples evolve independently from those of Cl^- (Fig. 4 a). Two different tendencies are also observed between Li^+ and Na^+ (Fig. 4 b). A certain amount of data from Uyuni form a roughly positive Li^+ versus Na^+ correlation. This trend is consistent with the correlation observed between Li^+ and Cl^- , and together suggest that the concentrations of Li^+ could be related to the equilibrium solubility of halite. Furthermore, the Pearson's correlation coefficient (R) corresponding to the mean concentrations of Li^+ , Cl^- and Na^+ across Andean salars ranges between 0.70 and 0.80 (Fig. 5). The second tendency depicted by the Li^+ versus Na^+ data trend includes most of the Altiplano brine samples, and forms an oblique line showing Li^+ increasing inversely to Na^+ , up to the concentrations of Uyuni samples RS15 and RZ1 (Figure 4 b). This pattern, which most likely corresponds to brine saturation with respect to halite, suggest that the Li^+ concentrations increase while halite precipitates.

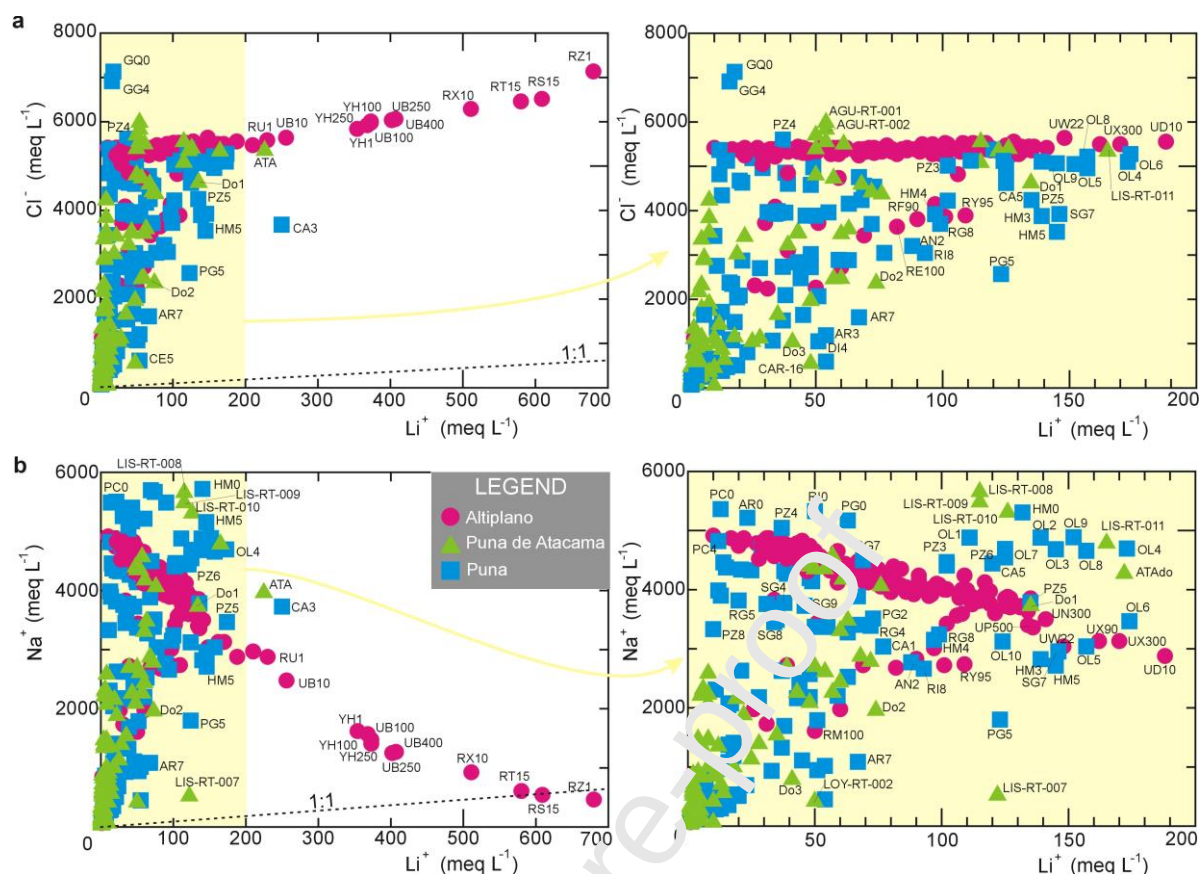


Figure 4. Scatter diagrams showing the variations of a) Li^+ versus Cl^- , and b) Li^+ versus Na^+ , in brines from Andean salars. Insets (yellow panels) offer a detailed view of the data displayed in the yellow boxes. Plotted values correspond to the concentrations detailed in Table 2.

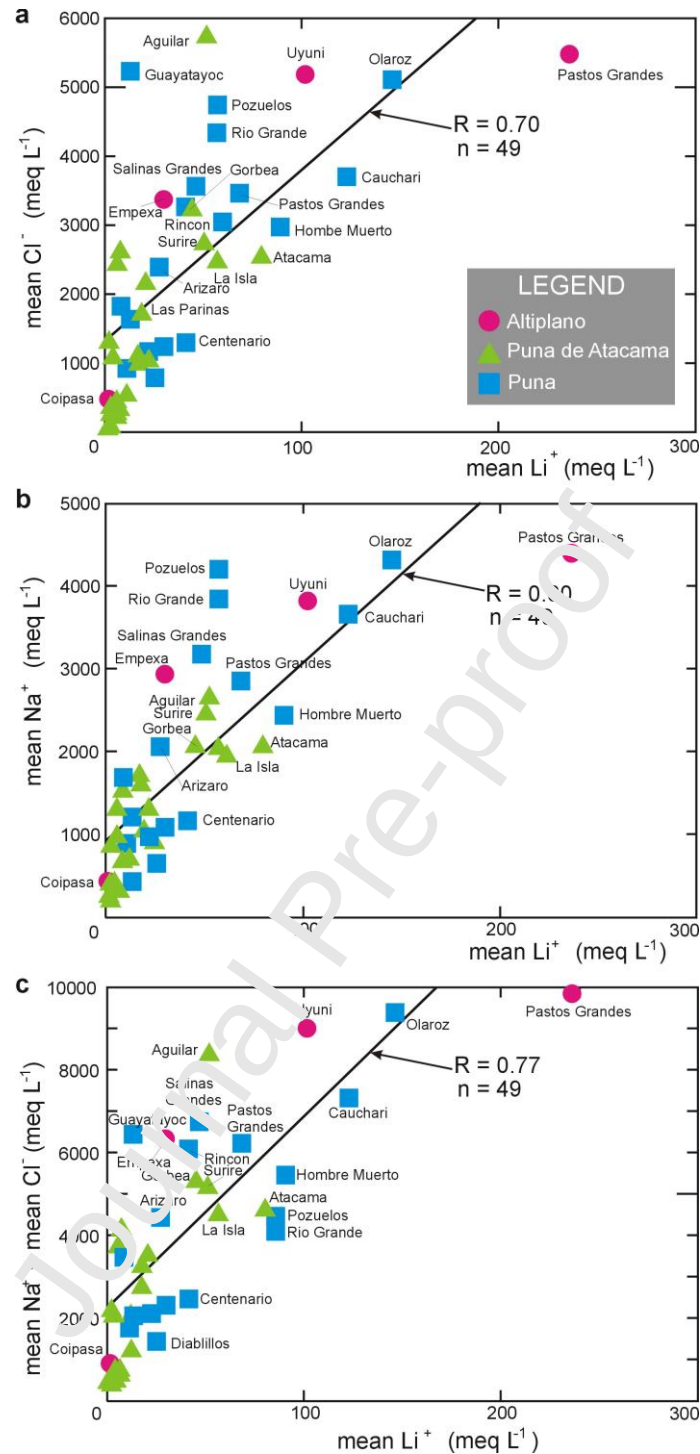


Figure 5. Scatter diagrams plotting the variations for the mean concentrations of a) Li^+ versus Cl^- , b) Li^+ versus Na^+ , and c) Li^+ versus $\text{Na}^+ + \text{Cl}^-$, in the Andean salars according to values presented in Table 3. The plotted mean Li^+ concentration for Atacama results from considering values reported by Moraga et al. (1974), Ericksen and Salas (1987), and Rischauer et al. (1999). It is important to note that this value differs from the globally accepted mean Li concentration in Atacama that is $1,400 \text{ mg L}^{-1}$ ($\sim 202 \text{ meq L}^{-1}$; Moraga et al., 1974; Ide and Kunasz, 1989; Kunasz, 2006). R is the Pearson correlation coefficient, n is the total number of points in the data set (i.e., the number of salars).

An additional interesting feature of the Altiplano brines is that Li^+ also seems to correlate, in different proportions, with K^+ , B, and Mg^{2+} (Fig. 6). The $\text{K}^+:\text{Li}^+$ ratios in most Altiplano brines array along a 1:4 trending line, a pattern that could be consistent with the equilibrium solubility of 1:4 salts (complex K-, Li-, Na- Cl salts, yet undetermined). Samples plotting along an oblique trend to the 1:4 proportion suggest saturation of the brine with respect to these compound (Fig. 6 a). When comparing mean values, it can be observed that the correlation R between Li^+ and K^+ reaches 0.68, which confirms this pattern reflects a Li^+ - K^+ interdependency (Fig. 6 b).

The concentrations of Li^+ and B in the Altiplano brines plot along a line that defines a 3:1 proportion trend (Fig. 6 c), and mean values are highly correlated ($R = 0.78$; Fig. 6 d). The concentrations of Li^+ also increase consistently with those of Mg^{2+} (Fig. 6 e), with the $\text{Mg}^{2+}:\text{Li}^+$ ratios defining trends with correlations of about 1:50 in Coipasa, 1:13 in Empexa and Uyuni, and $\sim 1:1$ in Pastos Grandes (Fig. 6 e). The observed proportionalities between Li^+ , B and Mg^{2+} have not been yet explained, and could correspond to the equilibrium solubility of complex borates and other salt or, alternatively, to the ionic influence of cations in exchangeable positions within clays. In any case, these proportionalities require further investigations. Interestingly, the Li^+ versus B pattern defined by the Altiplano brines is close to that displayed by brines from saline lakes in the Tibet Plateau (Fig. 6 c), which contains the second most important Li-brine type deposits on Earth (Zheng and Liu, 2009; Kesler et al., 2012; Li et al., 2019b, and references therein).

Mean Mg:Li ratios are 22 in Uyuni, 40 and 47 in the Empexa and Coipasa, respectively, and as low as 2 in Pastos Grandes (Fig. 6 C, Table 4). With Mg^{2+} means of $>15,000$ and $>12,000 \text{ mg L}^{-1}$, the Uyuni and Coipasa brines contain amongst the highest magnesium concentrations in the Andean plateau (Figs. 2 and 5 e, Tables 3 and 4).

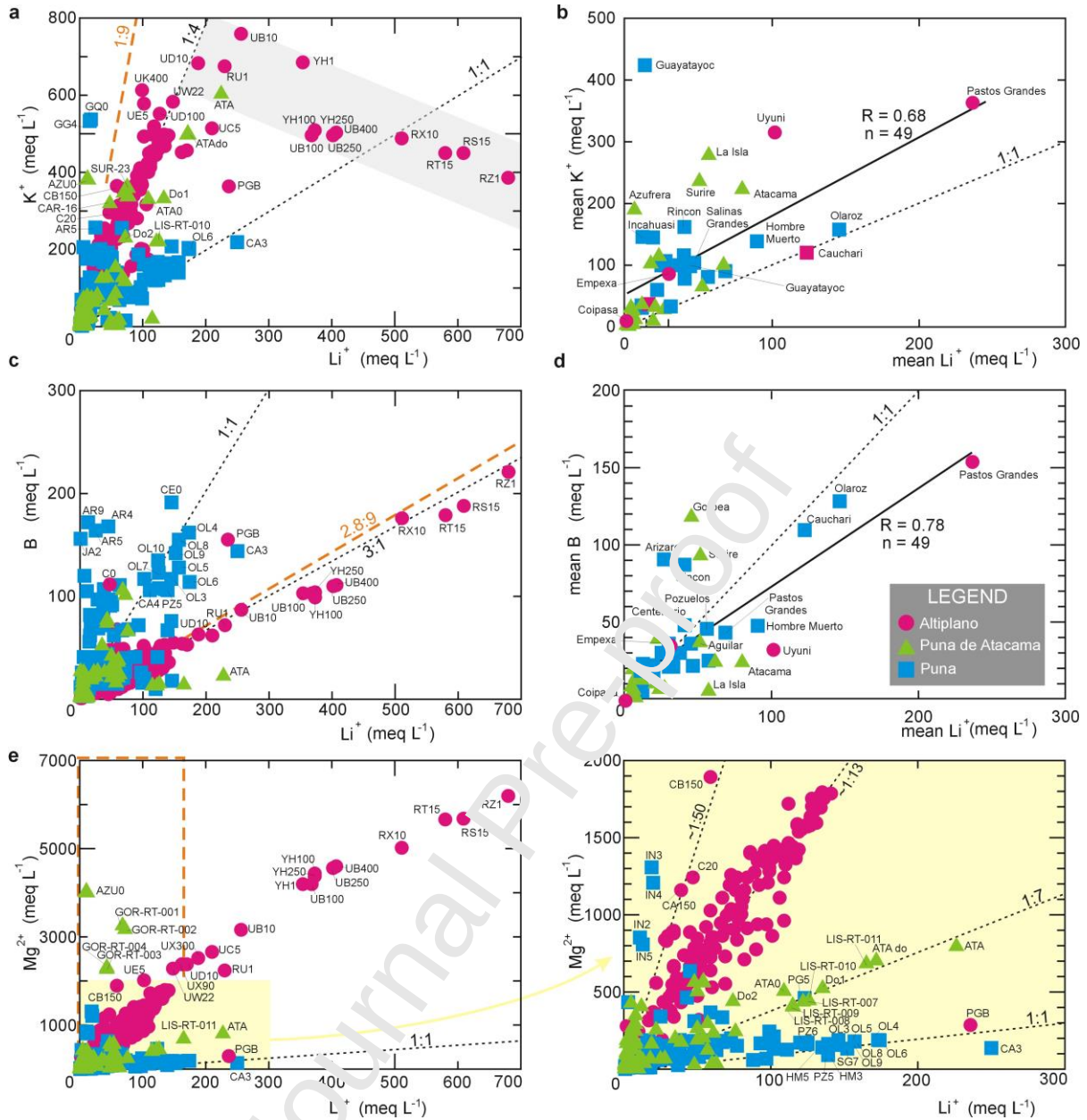


Figure 6. Scatter diagram, showing the variation between the concentrations of a) Li^+ and K^+ , b) mean Li^+ and mean K^+ , c) Li^+ and B, d) mean Li^+ and mean B, and e) Li^+ and Mg^{2+} . Values plotted in a), c), and e) are for brine compositions presented in Table 2. Scatter diagrams b) and d) plot mean concentrations according to values summarized in Table 3. Continuous line: R correlation coefficient, with n = the total number of salars. Dashed line: stoichiometric ratio. Orange dashed line and rectangle: stoichiometric proportions (panels a and c) and field (panel e) characterizing brines from the Tibetan Plateau (data from Li et al., 2019b).

4.2. Puna de Atacama Salars

Salt pans in the Puna de Atacama are located at altitudes between 2,300 (Atacama) and 4,500 (Pujasa, #15) m asl (Table 1, Fig. 1). The surfaces of these salars and their endorheic

basins are highly variable. With its 3,000 km², Atacama is the largest Chilean salt pan and, with a catchment area of 18,100 km², also the largest endorheic basin in the Chilean portion of the plateau. The smallest salt pans, such as Salar de la Laguna (#35) and Ignorados (#27), are only of 1 km² (Table 1). In the Puna de Atacama, only the Salar de Atacama is presently being mined for Li.

The brine chemistry of salars in the Puna de Atacama was comprehensively addressed by Risacher et al. (1999). Brines have highly variable salinity, with TDS ranging up to 370 g L⁻¹. The highest salt concentrations are observed in brines from Surire (#1), Atacama, and La Azufrera (#25), where mean values range between 178 and 267 g L⁻¹ (Tables 2 and 3).

According to their major chemical compositions, the Puna de Atacama brines are of the Na⁺ - Mg²⁺ / Cl⁻ - SO₄²⁻ type (Figs. 2 and 3 a). A few brines contain Mg²⁺ ≥ Na⁺ (e.g., samples IGN-04 and 05, PAJ-RT-004 and 018, and ACT-RT-006; Fig. 2), and/or Ca²⁺ ≥ Na⁺ and Mg²⁺ (e.g., samples ACT-RT-006, LOY-RT-002, MIC-10, and AGU-RT-002; Fig. 2). The concentrations of Cl⁻ are generally higher than those of SO₄²⁻, with few samples of low salinity having SO₄²⁻ > Cl⁻ (e.g., samples PUJ-RT-006 to 008, ACSS-RT-005 to 007, IGN-004 and 005; Fig. 3 a). The main characteristics of salar brines in the Puna de Atacama are their high Ca²⁺ and their relatively low K⁺ when compared to brines from neighboring parts of the plateau (Fig. 2).

The Na⁺ versus Cl⁻ concentration patterns are quite similar to those observed in the Altiplano brines (Fig. 3 b). Stoichiometric ratios ~1:1 between Na⁺ and Cl⁻ are consistent with the equilibrium solubility of halite (SI ≈ 0, e.g., sample Do2; Fig. 3 b), and samples plotting oblique to the 1:1 proportion trend suggest brine halite saturation and precipitation (SI > 0 and up to 0.47, e.g., samples AGU-RT-001, LOY-RT-002, LIS-RT-007; Fig. 3 b). Similarly to the Altiplano brines, the SO₄²⁻ and Mg²⁺ concentrations plot along the 1:1 proportional line, which is consistent with the equilibrium solubility of epsomite (MgSO₄ · 7H₂O), and/or other

Mg-bearing sulfates (Fig. 3 c). However, some brines do not match the $\text{SO}_4^{2-}:\text{Mg}^{2+}$ uniequivalent proportion trend, which implies the presence of other salts that are not in equilibrium with the brines (e.g., SI maxima for anhydrite and gypsum reach values of 1.07 and 1.10, respectively, in sample AGU-RT-001).

Li concentration in pan brines of the Puna de Atacama are very high. Indeed, the Puna de Atacama desert is known as having the richest Li brine-type deposits on Earth, and the salt pan of Atacama is the most important operating Li mine in world today, with mean Li grades of $1,400 \text{ mg L}^{-1}$ and maximum measured concentrations reaching $6,400 \text{ mg L}^{-1}$ (Moraga et al., 1974; Ide and Kunasz, 1989; Kunasz, 2006). Other than Atacama, high Li^+ concentrations were also measured, for instance, in La Isla (#30), Gorbea (#26), and Surire, where mean Li^+ grades are between 300 and 400 mg L^{-1} (Tables 2 and 3).

Despite that the Li^+ versus Cl^- and Na^+ concentrations distribute quite dispersedly, samples plot within the field defined by trends of the Altiplano brines (Fig. 4). Furthermore, mean Li^+ , Cl^- and Na^+ concentrations from the Puna de Atacama salars match the correlation lines characterizing other Andean brines (Fig. 5). Positive correlations could also exist between the concentrations of Li^+ and K^+ (Figs. 6 a and b). However, no evident correlation is observed between Li^+ and B (Figs. 6 c and d), whereas some samples arrays along the 1:7 proportional line, which might imply the existence of complex Li, Mg bearing salts (Fig. 6 e).

Despite that nearly uniequivalent proportions of Mg and Li are found in El Tara (#13) and Imilac (#21), these ratios are most often $\neq 1$. $\text{Mg}^{2+}:\text{Li}^+$ ratios <10 are observed in Pujsa, Loyoques (#16), La Isla, Las Parinas (#32), Surire, Maricunga (#38), and Atacama, whereas brines with Mg^{2+} concentrations about two orders of magnitude higher than those of Li^+ are found in Michincha (#7), Ignorados, and La Azufrera (Fig. 6 e, Table 4). This kind of brines, characterized by $\text{Mg}^{2+} \gg \text{Li}^+$, are also observed in brines from saline lakes in the Tibet Plateau (Fig. 6 e; Li et al., 2019b).

4.3. Puna Salars

The Puna plateau holds 17 major salars that are located at altitudes ranging between 3,269 (Incahuasi, #39) and 4,080 (Jama, #53) m asl (Table 1; Fig. 1). With the exception of giant Arizaro (1,708 km², #42) and the three smallest salars sizing less than 10 km² (Centenario, Diablillos, #44, and Ratones), salt pans surfaces range from 30 to 650 km² (Table 1). These salars are settled in endorheic basins with surfaces that mostly vary from 1,000 to 9,000 km². With 14,536 km², Rio Grande (#41) holds the largest basin catchment area, whereas the smallest basins correspond to the smallest salt pans (Table 1).

Amongst the Puna salt pans, only Hombre Muerto and Olaroz are being actively mined for Li. The brine chemistry in the Puna salar has been characterized by López Steinmetz et al. (2018) and López Steinmetz et al. (2020a). These brines contain highly variable saline content and ionic proportions. TDS as low as 6 g L⁻¹ have been found in some salars such as Jama, whereas TDS up to 381 g L⁻¹ were found at Olaroz, define the maximum measured values (García et al., 2019). Brines from the Puna salars are of the Na⁺ - K⁺ / Cl⁻ - SO₄²⁻ type in the north, of the Na⁺ - Mg²⁺ / Cl⁻ - SO₄²⁻ type in the south, and the SO₄²⁻ concentrations increase from south to north (Figs. 2 and 3 a).

Similar to the Atacama and Puna de Atacama, most of the Puna brines have Na and Cl concentrations that correlate positively along a 1:1 stoichiometric ratio, which is consistent with equilibrium solubility of halite (SI $\approx$ 0, e.g., samples AR9, PC7; Fig. 3 b). Some degree of correlation could exist between SO₄²⁻ and Mg²⁺ in some samples such as AR4 and AR5. However, as depicted in Figure 3 c, the Mg²⁺:SO₄²⁻ ratios do not match the 1:1 trend, implying the existence of other Mg²⁺- and SO₄²⁻-bearing salts (e.g., maximum SI values for anhydrite and gypsum range from -3.19 to 0.54 and -2.95 to 0.63, respectively, in samples IN3 and RG2).

Amongst Puna salars, maximum Li^+ values of 1,739 and 1,213 mg L^{-1} were found in Cauchari and Olaroz, respectively (Tables 2 and 4). In addition to these salt pans, where mean Li concentrations reach 860 and 841 mg L^{-1} , respectively, high Li-graded brines are stored in Hombre Muerto, Pastos Grandes (#49), Pozuelos (#48), Rio Grande, Salinas Grandes, and Rincon (#50), where mean Li^+ concentrations are between 280 and 570 mg L^{-1} (Table 3).

According to its geochemical behavior, Li variations in brines are expected to be consistent with those of other conservative solutes such as Cl^- and Na^+ . Positive correlations can exist between the concentrations of Li^+ , Cl^- and Na^+ in some cases (Figs. 4 and 5). Furthermore, Li also seems correlate positively with K^+ and B , and to a minor extent also with Mg^{2+} (Fig. 6). Interestingly, the concentrations of Li^+ and K^+ in the Olaroz and Cauchari (#51) brines display along the 1:1 ratio, whereas proportions in the remaining brines better fit the 1:4 dominant pattern defined by the Uyuni's brines (Figs. 6 a). Despite there is no clear pattern between $\text{Li}^+:\text{B}$ and $\text{Li}^+:\text{Mg}^{2+}$, nearly equivalent proportions are mainly observed in salt pans from the northern Puna (Figs. 6 c, d and e). However, brines from the Southern Puna instead show ionic proportional patterns mainly displaying parallel to the vertical axis (i.e., parallel to the B and Mg^{2+} axes), such as for Incahuasi, which brines match the trend $\sim 1:50$ ratio of the Coipasa brines (Fig. 6 e).

With the exception of Incahuasi, which brines contain high Mg^{2+} concentrations that are in the range of those observed in Uyuni and Coipasa (Fig. 6 e), remaining Puna salt pans, especially in the northern Puna, show the lowest Mg^{2+} values amongst the entire Andean plateau (Fig. 2, Table 4). These salars are characterized by brines having mean $\text{Mg}:\text{Li}$ ratios ≤ 11 , and some brines have exceptionally low ratios of 1 to 3, as the case of Ratones, Guayatayoc, Cauchari, and Olaroz (Table 4).

5. Discussion

5.1. Lack of Li geographical distribution

Andean Li-brine type deposits are found both in mature and in immature salars (Houston et al., 2011; Fig. 7 a and b). Andean mature salars, such as Atacama, correspond to halite dominated pans, whereas immature salars, like Uyuni and Olaroz, are mostly filled by clastic saline muds (Houston et al., 2011). Sometimes, mature and immature zones can be found in the same salt pan. For example, western Hombre Muerto corresponds to a mature pan, whereas its eastern side is an immature salar. An additional example is the Salar de Atacama. Here, the halite nucleus (i.e., mature salar) spreads for an area of 1,100 km² and ~1,000 m depth, in the southern part of the salar whereas the northern part is clastic dominated and gypsum rich (Boutt et al. 2016; Corenthal et al. 2016; and references therein).

However, the more often, Andean salt pans are complex combinations of crystalline salt layers, which are interbedded, in highly and variable proportions, with clastic fine -graded sequences (e.g., Salar del Rincon and Maricunga). In the practice, the predominant type tendency of a salt pan is revealed the more clearly during the brine extraction. Pumping in mature and immature pans implicates different responses of the water (i.e., brine) table due to the contrasting porosity (and permeability) of the substrate (i.e., porous salt pan and impermeable clay and muddy -rich deposits, respectively). During operations, pumping in a mature salar conduces to the development of a shallow depression cone of the water table around the pumping well, whereas in immature salars the cone deepens faster than it extends horizontally (Houston et al., 2011).

Three major noteworthy observations need to be addressed concerning mature and immature salars. Firstly, there is no strict rule and the areal extent of mature salars does not necessarily exceed that of immature salars (see Table 1). Secondly, brines in halite-dominated pans does not always contain higher Li concentrations than immature salars (Houston et al.,

2011; see Table 3). Thirdly, high Li -graded brines are not necessarily related to saline nucleus. Furthermore, deeper brines are not systematically richer in lithium. For instance, in the salt pan of Atacama the Li concentration isopleths form a pattern consisting of concentric Li grade zones with maximum values located in the southern part – and not in middle – of the halite nucleus (Moraga et al. 1974; Stoertz and Ericksen 1974; Ide and Kunasz 1989; Bevacqua 1992; Alonso and Risacher 1996; Carmona et al. 2000; Boschetti et al. 2007; Boutt et al. 2016; Corenthal et al. 2016). These concentric patterns are not the same at near surface levels as they are at depth. For example, if it is true that in the Uyuni salar Li concentrations increase concentrically and asymmetrically with depth, moving southward (Risacher and Fritz 1991; Fig. 7 c), in certain parts, Li concentrations do not change with depth, such as along the UI well where a constant Li concentration (300 mg l^{-1}) is reported from near surface down to 10 m depth (Fig. 7 c). An additional example of this is the Salar de Olaroz. The highest near surface concentrations of Li occur forming a pattern that can be followed along a NE-SW axis running through the middle of the salar (García et al., 2020; Fig. 7 d). Conversely, the pattern at ~200 m depth consists of two high Li level zones in the northern and southern parts of the salar, disrupted by an intermediate brine grade zone near the center of the pond (see García et al., 2020; Fig. 7 e).

Aridity is an important parameter controlling brine Li concentration along a vertical profile. By enhancing evaporation near the surface, it can cause shallower brines to have higher Li levels than those lying below. Clearly, a complex interplay of the above aspects to which add other factors such as the presence of hydrothermal springs and the role played by structures on Li-rich waters supply into the system, among many others listed by Godfrey et al. (2013; cf. also discussion below, sections 5.4 and 5.5), drive the singularity of each Andean salar. This notwithstanding, it is remarkable to observe that the major hydrochemical composition of brines is relatively similar across the Andean plateau (Fig. 8).

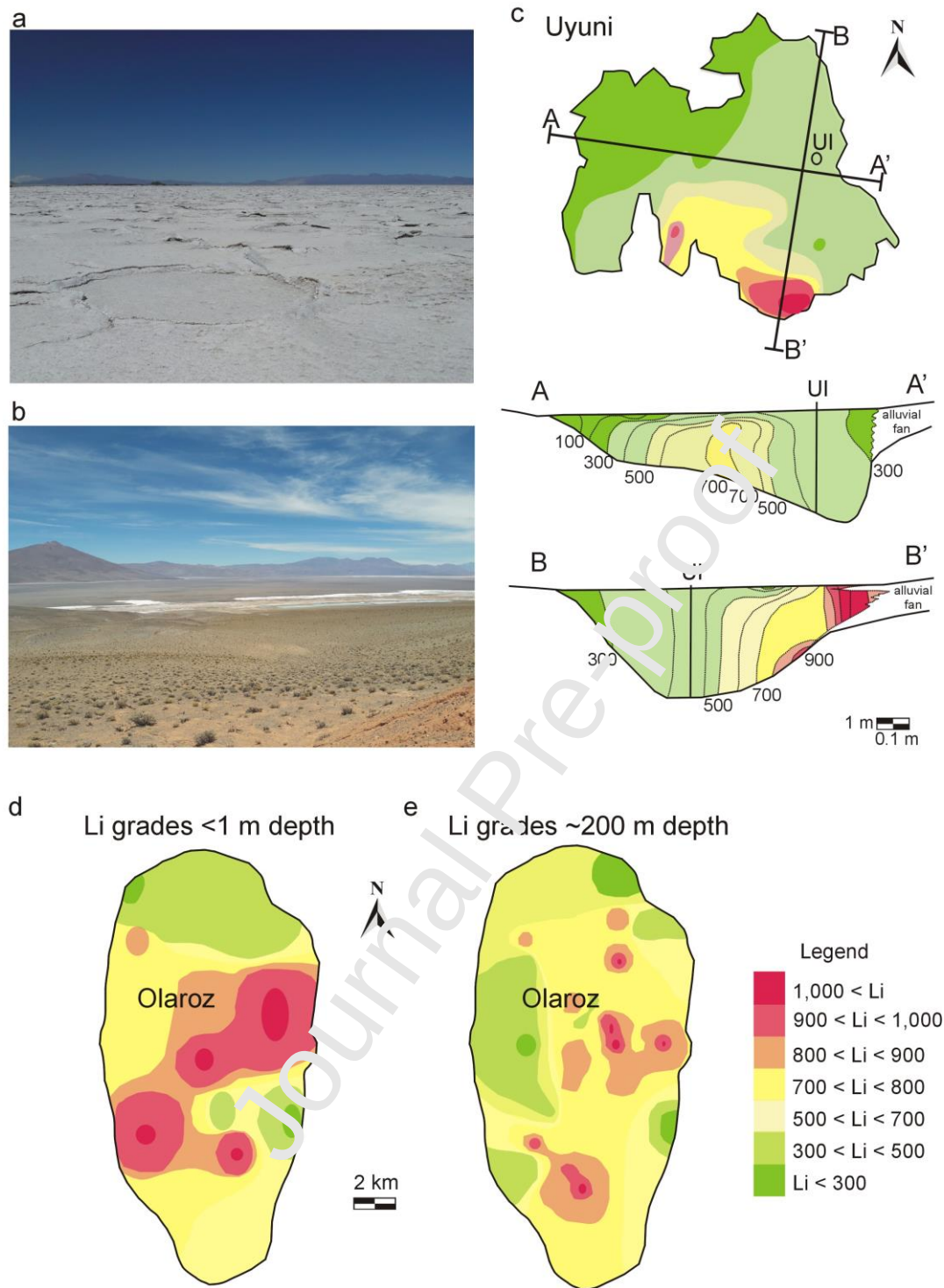


Figure 7. Pictures showing a) Salar de Pastos Grandes (Puna), and b) Salar del Rincón, respectively examples of mature and immature Andean salars. Notice the salt crust and the brown clastic surfaces. c) Map (upper panel) showing the Li isoconcentration curves in brines and the location of vertical profiles A-A' (middle panel) and B-B' (bottom panel) from Uyuni (modified from Risacher and Fritz, 1991). The location of well UI (referred in the text of section 5.1) is shown in panels. d and e) Map showing the concentration of Li in near surface (<1 m depth) and deep (~200 m depth) brines in Salar de Olaroz (modified from Garcia et al., 2020). Li concentrations are in mg L⁻¹.

A typical feature of evolved (evaporated) and highly saline waters is a composition marked by the presence of Cl^- and SO_4^{2-} , and a depletion in $\text{CO}_3^{2-}/\text{HCO}_3^-$ (Langbein, 1961; Hardie and Eugster, 1970; Eugster, 1980). Andean brines can be compared to those from Li-bearing saline lakes in the Tibetan Plateau (Li et al., 2019b, and references therein), despite obvious geological-environmental differences. In both cases, they commonly belong to the Cl^- - SO_4^{2-} type, and the hydrochemical variability is generally marked by variations in the major cations (Figs. 2 and 3 a). Our data compilation indicates that composition with a Na^+ - Mg^{2+} signature largely predominate in the whole Andean plateau (and in Tibet), with the exceptions of Uyuni (Mg^{2+} - Na^+ signature) and the Northern Puna salars (Na^+ - K^+ signature). Brines with high Mg^{2+} concentrations occur in the Altiplano, whereas they are generally depleted in this cation in the Northern Puna. Finally, Ca^{2+} shows the highest concentrations in the Puna de Atacama, west of the modern Andean volcanic arc (Fig. 8).

The association between Li and B evidenced by our data (Figs. 6 c and d) confirms the existence of a link between these two chemical elements in Andean evaporitic systems, as was indicated by Catalano (1964), Alonso et al. (1988), Alonso et al. (1991), Kistler and Helvaci (1994), and observed in other parts of the globe (e.g., Helvaci et al., 2004, and references therein). However, isotopic studies have shown that, in the Andes, Li and B share only a partial common origin (Kaseman et al., 2004). Two distinctive origins have been suggested as sources for boron: for the western plateau, isotopic values indicate a volcanic contribution, mostly Neogene meso-silicic pyroclastic rocks and related hydrothermal systems, whereas weathering of volcanoclastic sequences from the Paleozoic basement are the probable source of B in the eastern plateau (Kaseman et al., 2004). The Paleozoic basement is also considered to be the primary source of Li (Egenhoff and Lucassen, 2003; Peralta Arnold et al., 2017; García et al., 2019; Meixner et al., 2019). Such common origin is reflected by the strong association between Li and B ($R = 0.78$; Fig. 6 d). However, their concentration ratios grading

up to 3:1, and the fact that they are mostly characterized by $\text{Li} > \text{B}$ south of $\sim 22^\circ\text{S}$ and $\text{B} > \text{Li}$ to the north of it, point to the absence of unambiguous $\text{Li}:\text{B}$ patterns, consistently with B and Li being sourced from different lithologies. While it appears clear that further studies on the Li-B geochemical relationships are necessary (e.g., Lopez Steinmetz et al., 2020a), it seems safe to suggest that B may not be an appropriate prospective tool for lithium, at least not in the Andean region.

Despite that major brine chemistry, as discussed above, shows some degree of geographical organization with respect to compositions (Fig. 8), there is no obvious Li^+ distribution across the Andean plateau. Geographic patterns are also not observed for K, B, and Mg. The only common trend shown by those plots is that, as a whole, maximum Li^+ values were reported from salt pans located in the central area of the plateau, between $66^\circ 30' - 68^\circ 30' \text{ W}$ and $20^\circ - 24^\circ \text{ S}$ (Figs. 9 a and b). This spatial distribution is consistent with that of other cations, such as Mg^{2+} (Figs. 9 c and d), confirming that the most saline brines and highest ionic concentrations occur in the middle of the Andean plateau desert. It would thus be expected that solute concentrations would decrease in salt pans located towards the desert borders. This pattern is intriguing and clearly worthy of further studies. In summary, Li concentrations across the Andean plateau lack a clear geographic distribution pattern, other than that depicted in Figure 9.

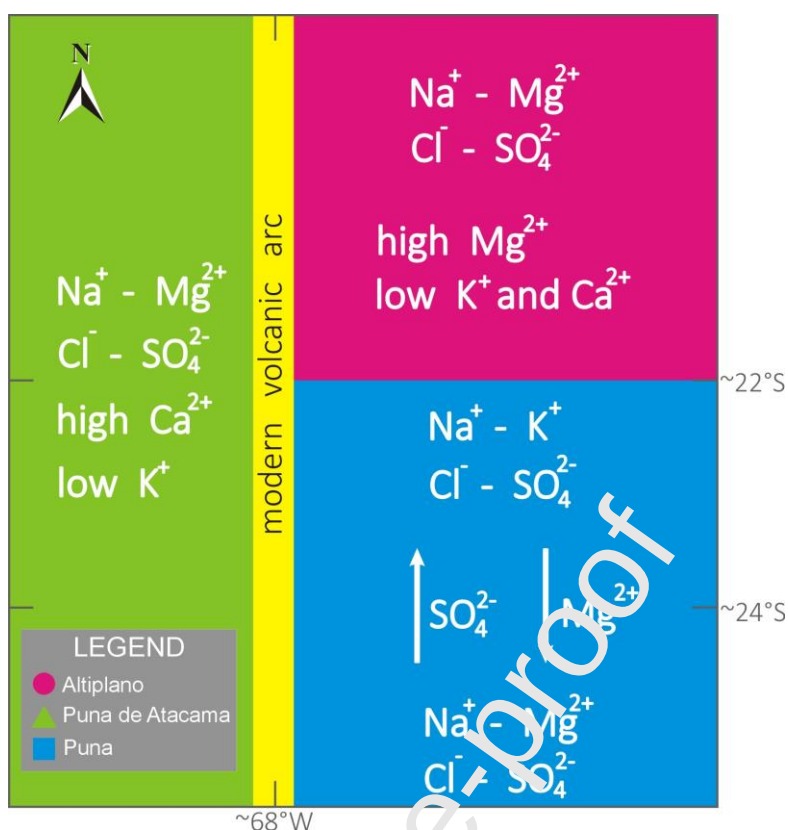


Figure 8. A schematic illustration of the internal subdivision of the Andean plateau (see legend), summarizing major brine chemistry in salt pans across the Lithium Crescent. “Modern volcanic arc” (yellow area) refers to the present-day situation; the past Cenozoic situation is not considered in this scheme.

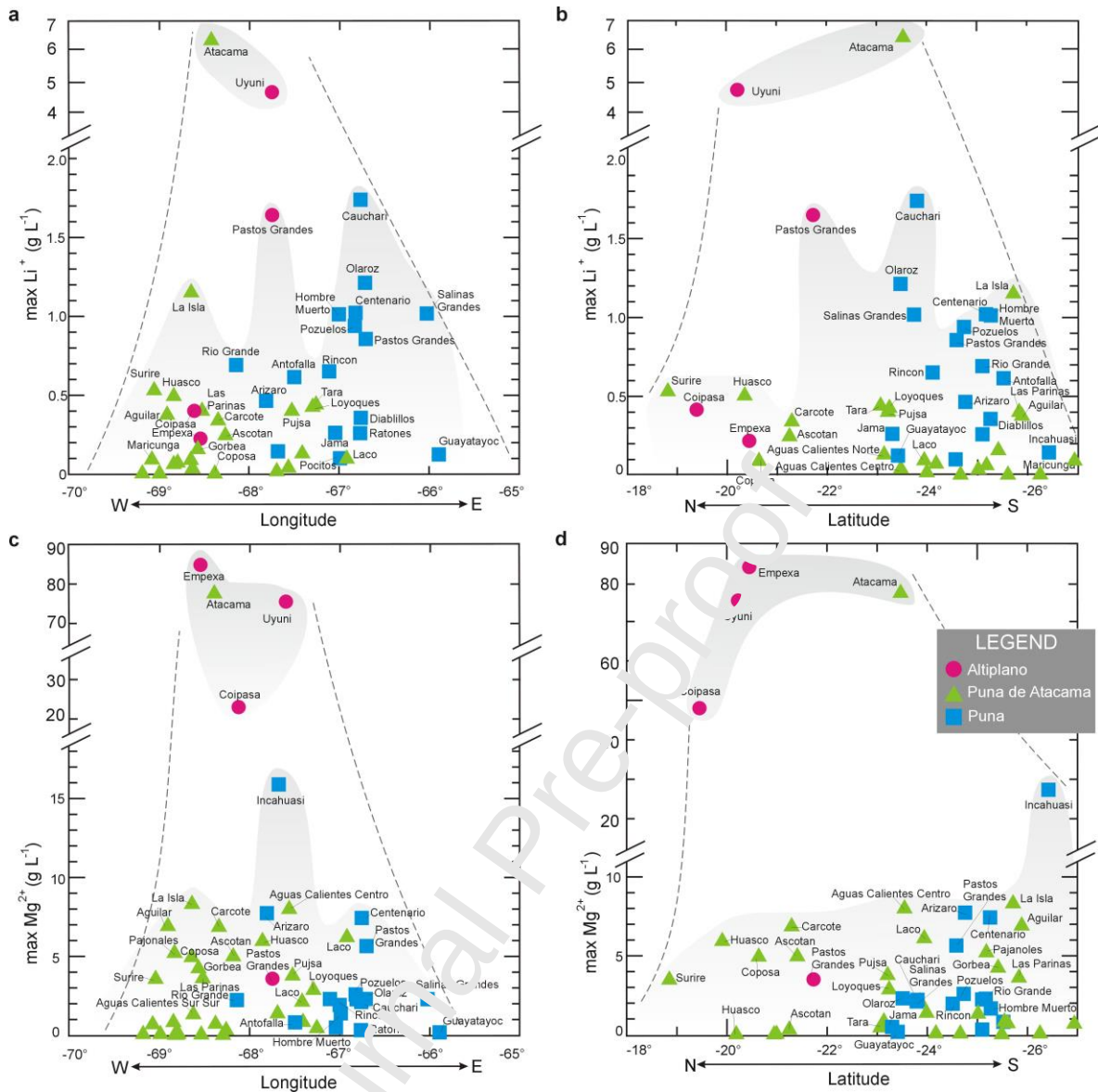


Figure 9. Scatter diagrams showing the maximum Li^+ (upper) and Mg^{2+} (bottom) concentrations according to longitude (a and c), and latitude (b and d) of salars across the Lithium Crescent. Notice that the considered maximum Li^+ and Mg^{2+} concentrations for Atacama are of 6,400 and 80,000 mg L^{-1} , respectively (Moraga et al., 1974; Ide and Kunasz, 1989; Kunasz, 2006). Plotted data correspond to values summarized in Table 4.

5.2. Link between salt pan and endorheic basin areas

The surfaces of the 55 salt pans studied across the Andean plateau (Fig. 1) appear to be related to those of their respective basin catchments, as revealed by the very good correlation obtained comparing their areas: $R = 0.89$ (Fig. 10 a). Two proportional size ranges are observed: basin catchments of Uyuni, Atacama and Arizaro are 5 times larger than their

salt pans, i.e., have a 1:5 size ratio (Fig. 10 a), whereas for the 52 remaining sites, salt pan to basin size proportions are close to the 1:10 ratio (Figs. 10 a and b). Coipasa and Guayatayoc are the two salt pans that least fit either of these relationships (these two cases are discussed further down).

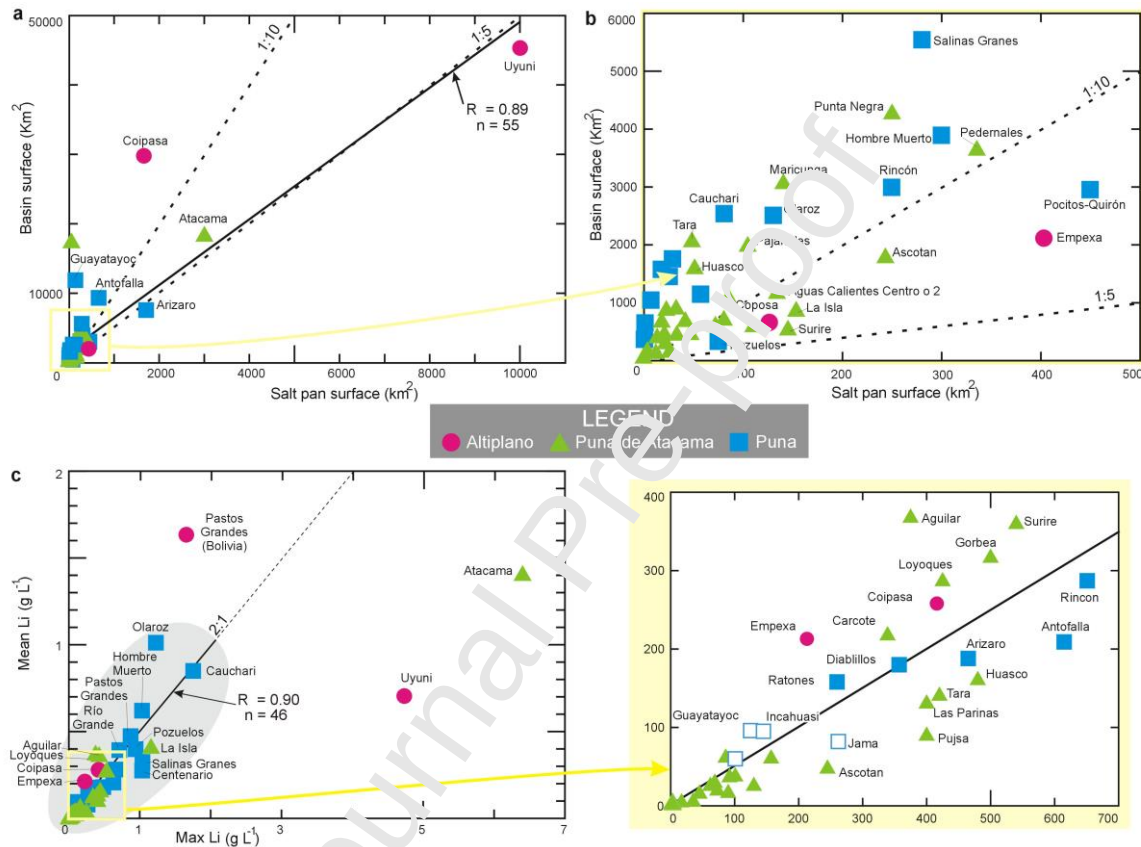


Figure 10. a and b) Scatter diagrams showing the relations between the surfaces of salt pans and their respective basin catchments. a) The correlation $R = 0.89$ was computed by considering all 55 Andean salt pans according to values summarized in Table 1. Note that the correlation line (continuous stroke) is close to the 1:5 proportion (dashed line). b) This panel expands the inset (in yellow) and plots data for the smallest salt pans. Note that most salt pans group close the 1:10 proportion. c) A scatter diagram plotting the relationship between the maximum (*Max*) and mean Li concentrations according to values summarized in Table 4. The regression R (continuous line) coincides with the stoichiometric proportion of 2:1 (dashed line) for 46 salt pans (n , gray area). Values for *max/mean Li* ratios are of 1 in Pastos Grandes (Bolivia), 7 in Uyuni, and 11 in Atacama. The inset offers an expanded view of the data displayed in the yellow box of panel c. R is the correlation coefficient (continuous lines), n is the number of salt pans.

The good correlation between salt pan and endorheic basin areas and the two proportional size ranges are very interesting patterns that undoubtedly deserve further specific investigation. Although this is beyond the purpose of this paper, it can be suggested that these relationships may arise from common trends in regional geological history, including lithology (i.e., substrate, tectonics, volcanism, etc.) and exogenous processes (e.g. climate-related such as regional aridity and its effect on rock weathering and erosion), across the Andean plateau.

Li-bearing Andean salt pans occur exclusively within endorheic basins. The onset of endorheism requires the convergence of the following parameters: suitable basin configuration (topographic barriers surrounding low lying areas), aridity (low precipitation – P – and high evaporation – E – rates, where $P < E$), hard substrate thus low erosion rates (in order for range-crossing rivers to fail incising deeply into the ranges and inhibit basin capture), and low aggradation rates (in order for sedimentation not to overfill the isolated area), amongst other variables (Sobel et al., 2003; Hilley and Strecker, 2005; García-Castellanos, 2006; Tremblay et al., 2015). Basement inherited heterogeneities (Hongn et al., 2007), Cenozoic Andean tectonics (actively uplifting ranges) and Neogene plateau rise were key factors for the formation of endorheic basins in the plateau, while the arid climate (Garreaud, 2009) has ensured their preservation (Vandervoort et al., 1995; López Steinmetz et al., 2020b). Within an endorheic basin, weathering and erosion of the catchments supply the suspended and dissolved load that is transported by rivers towards the low-lying area, where sediments and other products accumulate. Under arid conditions, salt pans form on these low-lying and hydrologically isolated areas (Melvin, 1991; Warren, 2010). Consequently, there is a clear link between the formation of internally drained areas and salt pans. However, as natural processes are typically heterogeneous and complex (Becker and Braun, 1999; Paola et al., 2009), this link clearly does not imply that we can estimate or model the size of endorheic

and saline units, let alone predict whether there might be proportionality between them. It could only be argued that if large catchments are more capable of generating a greater amount of suspended and dissolved load than smaller ones, then under similar conditions (i.e., geological history including lithology, deformation, volcanism and related hydrothermal processes, climate, etc.), large catchments would be required for the largest salt pans to form. For this reason, the fact that the size of salt pans adjusts proportionally to the size of endorheic basins, as revealed by our observations across the Andean plateau (Figs. 10 a and b), is a fascinating configuration for landscape studies. The salt pan/basin size proportionality could apply to other endorheic basins in arid regions. For instance, the Qaidam Basin (*ca.* 94°E - 38°N) in the northern Tibetan Plateau holds world-class Li-brine type deposits comprising 80% of the Li-brine resources found in China (Keslar et al., 2012). The basin's surface is 121,000 km², one-fourth of which covered by numerous saline lakes and playas (Yu et al., 2013). According to this, the ~1:1 salt pan/basin size ratio in Qaidam is close to the proportion found in Uyuni. The proportionality between the surfaces of salt pans and their endorheic basins should thus be checked in detail in other Tibetan Plateau basins and in other regions with internal drainage, in order to confirm the application of this relationship to other parts of the globe.

The poor salt pan-basin size association observed in the Guayatayoc and Coipasa salars appears to result from relatively late processes, i.e., younger than the basins. In the case of Guayatayoc, its basin is oversized with respect to the size of its salt pan (11,805 km² and 140 km², respectively). However, nearly half of the current extent of this basin formed in the Pleistocene, through the capture of the western watershed areas (López Steinmetz and Galli, 2015). This process resulted in the formation of a large (>500 km²) distributive fluvial system (*sensu* Weissman et al., 2015), which lead to the subdivision of the precursor flats and the formation of two individual salars and respective basins, Salinas Grandes and Guayatayoc.

This means that, before the Pleistocene, the unified surface area of the basins (Salinas Grandes + Guayatayoc; ~11,000 km²?) would correlate with the area of the precursor salt pans (Grandes + Guayatayoc + megafan, ~920 km²?). In the case of Coipasa and its oversized basin area, satellite imagery of geomorphological features suggests that the northern half of the basin's catchments (north of 18°50'S) is a remnant of an ancient independent drainage system that could have been incorporated into the Coipasa basin through the capture of the Lauca River.

5.3. Mean Li concentrations are half the maximum Li measured

Brines in Andean salt pans show a 2:1 proportionality between maximum Li values and mean concentrations (Fig. 10 c), with a correlation $R = 0.90$ for 46 salt pans. Atacama, Uyuni and the Bolivian Pastos Grandes do not fit this correlation, with maximum to mean Li proportions of 11:1, 7:1, and 1:1, respectively. The high degree of correlation together with the exceptional number of salt pans fitting the 2:1 proportion make this pattern a substantial feature across the Central Andes. It means that maximum and mean Li concentrations can be considered as mutual proxies for surveying Li brine-type deposits. Accordingly, an indicative value of the mean concentration of Li brines in a salt pan can be estimated as half the value of the maximum measured, and vice versa, a relationship that can be expressed as:

$$\text{mean Li} \approx \frac{1}{2} \text{max Li} \quad (1)$$

In the case where only few grade data were collected in one salt pan, the mean Li grade would be hard to determine. The difficulty in obtaining representative mean (and *max*) Li values arises from the need to acquire a large dataset in order for the mean Li (and *max*) grade to be confidently considered as representative of the real potentiality of the deposit in question (see Houston et al., 2011). However, despite the time elapsed since the beginning of the Andean Li rush, in general, the hydrochemistry of only a limited number of samples is

available for each of Andean salt pans in the scientific literature, even today. In fact, a relatively restricted number of data is also a typical situation in the initial phases of most mining projects. This clearly represents a major drawback when estimating the mean Li grades (and *max*) of mining prospects. In this context, the formulation (1) proposed for predicting average Li values can provide a useful approach. It is important to note that the *mean* Li value obtained through equation (1) is valid from a statistic and regional perspective. Obviously, it does not replace the specific average value of a deposit obtained from a large dataset, but provides a useful order-of-magnitude indication which that can be quite valuable (see for example the case of Salar de Olaroz in Fig. 10 c and in Table 4, where *max* Li measured is of 1,213 mg L⁻¹ whereas the average Li value that result from mining operations is of 841 mg L⁻¹; Garcia et al., 2019).

The usefulness of the formulation proposed above lies in the fact that at any point in the exploration of a Li brine-type deposit, the maximum measured Li concentration can be used to predict an indicative average value of its grade. The formulation (1) thus defines a dynamic approach to mean Li values, which implies that the predicted *mean* Li will change and evolve as the dataset increases during prospection.

5.4. Li grade as function of salt pan / basin geomorphology

As seen in previous sections, a regional assessment has made it possible to define a relationship between mean and maximum Li concentrations for Andean salars, and to identify a proportionality between the surfaces of the salt pans and basins. In order to test these proportionalities, the concentrations of Li, mean and maximum, have been addressed with respect to the area of the salt pan or its basin catchments (Fig. 11). Despite the fact that the link between Li concentrations and surfaces does not follow a definite proportionality, there is some degree of relationship between Li grade and salt pan size. Larger salt pans do host, by

and large, higher Li-grade brines than smaller pans (Fig. 11 a). This proportionality seems to change according to grade-size scales: i) a relationship of increasing Li with salt pan size is evident for the larger salt pans, i.e., more than 300 km² ($R = 0.83$, $n = 7$; Fig. 11 a); ii) this Li-grade/pan-surface relationship is also observed for salt pans having surfaces between 200 and 300 km² ($R = 0.87$, $n = 4$; Fig. 11, inset of panel a); and iii) a Li-grade/pan-surface relationship is also observed in those less than ~150 km² ($R = 0.63$, $n = 23$, Fig. 11 a, see also details in panels b and c). These three proportionality ranges comprise most (i.e., 34) of the Andean salt pans, with 15 salt pans not fitting any relationship (Fig. 11 b).

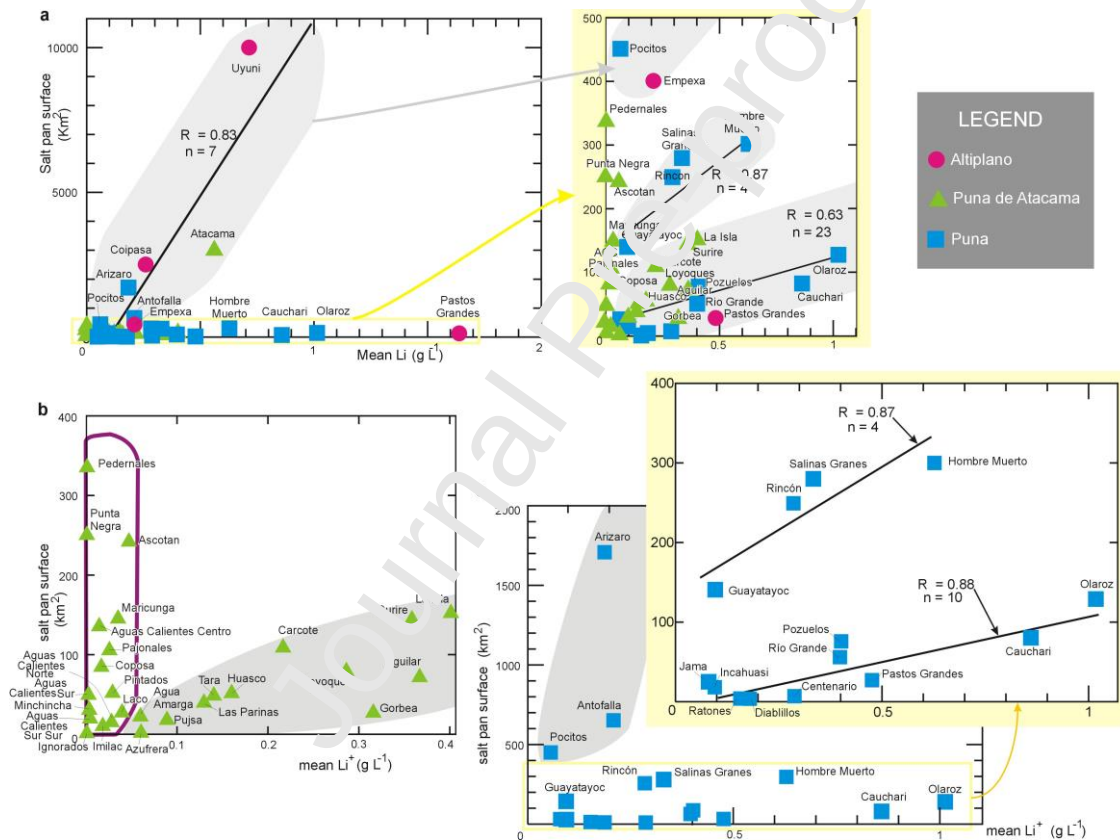


Figure 11. Scatter diagrams showing the relations between mean Li concentrations and pan surfaces for a) the 49 salt pans in the Andean plateau, b) salt pans from the Puna de Atacama, and c) salt pans from the Puna. Insets offer detailed views of the data displayed in the yellow boxes of panels a) and c). Gray areas group salt pans where there is some degree of proportionality between the mean Li values and the salt pans surfaces. In panel b, the purple thick line contours the 13 salt pans lacking a relationship between Li grade and salt pans surface. R is the correlation coefficient (continuous lines), n is the number of salt pans.

Arguably, the dependence of Li concentration on processes occurring at the basin scale is not the most widespread concept, particularly in the Andean and Tibetan literature. In most studies, the rate of supply of Li-bearing waters from hydrothermal springs is deemed as being the essential parameter in controlling Li grades (e.g., Davis et al., 1986; Ide and Kunasz, 1989; Kesler et al., 2012; Godfrey et al., 2013). However, as discussed in section 5.1, thanks to recent investigations on isotopic systematics, it is now apparent that the primary sources of Li in the Andes, including what is supplied by hydrothermal springs, are restricted varieties of lithologies of the Paleozoic basement that underlies the plateau (Egenhoff and Lucassen, 2003; Peralta Arnold et al., 2017; García et al., 2012; Meixner et al., 2019).

Likewise, not to be confused are the concepts of Li grades and Li reserves. Larger salt pans (i.e., of greater areal extent) do not necessarily contain greater Li reserves. This is because the total Li of a brine-type deposit (i.e. its reserves) is provided by the physical parameters of the aquifer (real size – i.e. horizontal areal extent plus thickness of the aquifer –, hydraulic conductivity, transmissivity, etc.), in addition to the actual Li grade in the brine.

Up to now, and contrarily to reserves, the sizes of salt pans or basins have not been related to Li levels, in the Andes or elsewhere, nor have they ever been considered as an integral condition for higher Li graded brines. However, regional data from the Andes show some degree of proportionality between Li concentrations and the surface area of basins and pans. This might imply that, under otherwise comparable conditions (i.e., substrate and surface lithology, characteristics and density of structures, number, density and hydrochemistry of hydrothermal sources, climate, etc.), large salt pans in endorheic basins would generally contain brines with a higher lithium content than smaller ones.

5.5. Lithium Crescent: when basin size matters

The most relevant factors governing Li grades in salt pans are the existence of input sources of Li, hydrological isolation, and aridity (Munk et al., 2016). Based on the general tendency of increasing Li concentrations with salt pan/basin sizes (Fig. 11), it follows that Li grades should be also (at least partially, in addition to the factors mentioned above) dependent on a geomorphological feature: the salt pan area (or its catchment area; Fig. 12). As discussed above, under analogous conditions (i.e., substrate and surface lithology, characteristic and density of displaying structures, number, density, and hydrochemical characteristics of springs, climate, etc.), larger salt pans should be expected to contain higher Li-graded brines than smaller ones, which would be a very useful criterion for surveying brine-type deposits. A correspondence between Li grades and salar sizes may reflect the importance of basin scale processes such as rock weathering, isolation, evaporation, and time (López Steinmetz et al., 2020b). This would be consistent with the model proposed for the formation of the Atacama's and Olaroz's brines, which took place in a near-surface setting through geochemical processes such as low-temperature weathering, evaporation, formation of transition-zone brines, and ultimately crystallization of halite to increase the concentration of Li in the brines (Munk et al., 2018; Franco et al., 2020). As already mentioned in section 5.1., other studies have reported Li isotopic data showing that volcanic and Paleozoic basement rocks represent the primary source for Li in the Andean plateau (Egenhoff and Lucassen, 2003; Peralta Arnold et al., 2017; García et al., 2019; Meixner et al., 2019). These models are consistent with the absence of a clear geographical distribution of Li in salars across the plateau, because Li is sourced from a lithological unit that is widespread the Paleozoic basement that underlies the salars across the plateau. On the other hand, the fact that Li levels increase with increasing salar size suggests that other processes are acting at the scale of the basin, and these are likely tied to geomorphology, and, presumably, the age of the basin. The implication of the latter would be that older basins had more time than younger ones to accumulate the products of

weathering and evaporation. Time dependence of Li grades implies a significant role of the age of endorheism onset, of the history of Li supply and of the persistence of arid conditions.

In summary, the integrity of the available regional data evidences some degree of correspondence between Li grades and salar sizes. This thus implies that not only the largest but also the oldest salars would be the ones expected to contain the largest Li resources. The fact that Li grade could be a function of salt pan/basin geomorphology may provide an insight on new approaches toward understanding the formation of Andean salars, and, more generally, brine-type deposits worldwide.

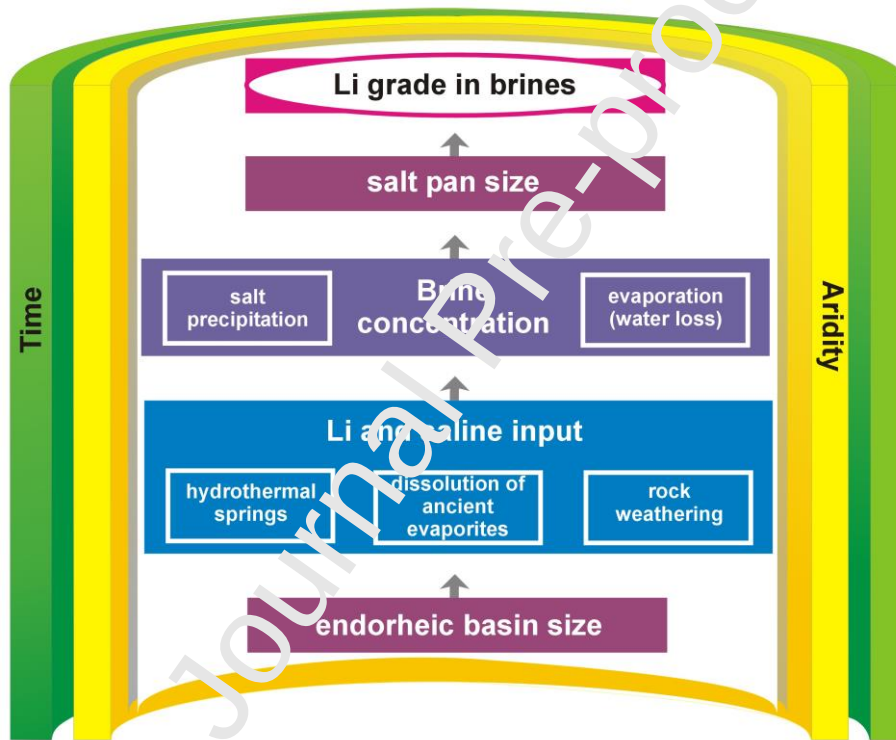


Figure 12. A schematic flow diagram illustrating Li -related processes from basin to salt pan (upwards). It illustrates the interplay between hydrological processes, climate and time, leading to Li accumulation (grade) in Andean brine-type deposits.

6. Conclusions

- The area involving all of the Andean Li-bearing salt pans extends beyond the Lithium Triangle and corresponds in fact to a curved crescent shape. We propose it be referred to as the Lithium Crescent.
- Andean brines are of the $\text{Cl}^- - \text{SO}_4^{2-}$ type, and the compositional variability is marked by major cations: $\text{Na}^+ - \text{Mg}^{2+}$ signatures largely predominate, with the exceptions of the $\text{Mg}^{2+} > \text{Na}^+$ signature of Uyuni, and the $\text{Na}^+ - \text{K}^+$ signature in the Northern Puna salars (Argentina). High Mg^{2+} concentrations occur in the Altiplano (Bolivia), and Ca^{2+} has highest values in the Puna de Atacama (Chile).
- Li lacks of a clear geographical distribution pattern across the Lithium Crescent, other than the fact that maximum Li^+ values occur in the central area of the Andean plateau, between $66^\circ 30' - 68^\circ 30' \text{ W}$ and $20^\circ - 24^\circ \text{ S}$. Such an absence of a geographical distribution in the Li pattern is likely a consequence of the fact that the primary source of Li is the Paleozoic basement, which underlies all salt pans across the Andean plateau.
- Li-bearing Andean salt pans are exclusively hosted in endorheic basins. Across the Lithium Crescent, sizes of salt pans are proportionally related to the extent of their endorheic basin surface. The size ratio for the Qaidam Basin in the Tibetan Plateau is close to the proportions found at Uyuni. The salt pan/basin surface proportionality should thus be checked in detail in other regions of internal drainage, in order to confirm the application of this relationship to other parts of the globe.
- In the Andes, measured maximum Li values (max Li) are twice the mean Li concentrations: the equation $\text{mean Li} \approx \frac{1}{2} \text{max Li}$ can be employed to predict indicative mean grades during brine-type deposit surveying in the Lithium Crescent.
- The concentrations of Li (mean or maximum) can be addressed indistinctly with respect to the area of the salt pan or its basin catchments. Larger salt pans host, in general, higher-grade Li brines than smaller ones. This proportionality changes according to grade-size scales of

three groups: the largest salt pans of more than 300 km²; those having surfaces between 200 and 300 km², and salt pans of less than ~150 km².

- Li levels depend on basin-scale processes, on geomorphology and, presumably, also on the age of the basin: therefore, it is likely the largest and oldest salars that are expected to hold the greatest Li concentrations.

ACKNOWLEDGMENTS

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. We wish to thank to C. Helvaci and five anonymous reviewers for their helpful comments that greatly improved this manuscript, as well as J.-A. Sanchez-Cabeza for editorial handling. The authors declare no conflict of competing financial nor non-financial interests in relation to the work herein.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

- Adad, M.J., López Steinmetz, R.L., Dávila, F.M., 2020. Seismic interpretation and Cenozoic tectonic evolution of the Pozuelos Basin, Andean Plateau, Argentina. *Journal of South American Earth Sciences*. doi:10.1016/j.jsames.2020.102938.
- Allmendinger, R.W., Ramos, V.A., Jordan, T.E., Palma, M., Isacks, B.L., 1983. Paleogeography and Andean structural geometry, northwest Argentina. *Tectonics*. 2 (1), 1-16.

- Allmendinger, R.W., Gubbels, T., 1996. Pure and simple shear plateau uplift, Altiplano-Puna, Argentina and Bolivia. *Tectonophysics*. 259 (1-3), 1-13.
- Allmendinger, R., Jordan, T., Kay, S., Isacks, B., 1997. The evolution of the Altiplano–Puna plateau of the Central Andes. *Annual Reviews on Earth and Planetary Sciences*. 25, 139-174.
- Alonso, H., Risacher, F., 1996. Geoquímica del Salar de Atacama, parte 1: origen de los componentes y balance salino. *Revista Geológica de Chile*. 23 (2), 113-122.
- Alonso, R.N., Helvaci, C., Sureda, R.J., and Viramonte, J.G., 1998. A new Tertiary borax deposit in the Andes. *Mineralium Deposita*. 23, 299-305.
- Alonso, R.N., Jordan, T.E., Tabbutt, K.T., Vandervoort, D.S., 1991. Giant evaporite belts of the Neogene Central Andes. *Geology*. 19, 401-404. doi:10.1130/0091-7613(1991)019<0401:GEBOTN>2.3.CO;2
- Alonso, R.N., Bookhagen, B., Carrapa, B., Coutand, I., Haschke, M., Hilley, G.E., Schoenbohm, L., Sobel, E.R., Strecker, M.R., Trauth, M.H., Villanueva, A., 2006. Tectonics, climate, and landscape evolution of the southern central Andes: the Argentine Puna Plateau and adjacent regions between 22 and 30° S, in: Oncken, Chong, O., Franz, G., Giese, P., Götze, H.-J., Ramos, V.A., Strecker, M.R., Wigger, P. (Eds.), *The Andes Active Subduction Orogeny*. Springer, Berlin, pp. 265-284.
- An, J.W., Kang, D.J., Tran, K.T., Kim, M.J., Lim, T., Tran, T., 2012. Recovery of lithium from Uyuni salar brine. *Hydrometallurgy*. 64-70, 117-118.
- Babeyko, Y.A., Sobolev, S.V., Trumbull, R.B., Oncken, O., Lavier, L.L., 2002. Numerical models of crustal scale convection and partial melting beneath the Altiplano-Puna plateau. *Earth and Planetary Science Letters*. 199, 373-388.
- Baby, P., Rochat, P., Mascle, G., Herail, G., 1997. Neogene shortening contribution to crustal thickening in the back arc of the Central Andes. *Geology*. 25 (10), 883-886.

- Belmonte, A., 2002. Krustale Seismizität, Struktur und Rheologie der Oberplatte zwischen der Pr7kordillere und dem magmatischen Bogen in Nordchile (228–248S). PhD thesis, Freie Universität Berlin, Germany.
- Banks, D., Markland, H., Smith, P.V., Mendez, C., Rodriguez, J., Huerta, A., Saether, O.M., 2004. Distribution, salinity and pH dependence of elements in surface waters of the catchment areas of the Salars of Coipasa and Uyuni, Bolivian Altiplano. *J. of Geochem. Explor.* 84, 141-166.
- Becker, A., Braun, P., 199. Disaggregation, aggregation and spatial scaling in hydrological modelling. *Journal of Hydrology.* 217, 239-252.
- Bevacqua, P.S.J., 1992. Geomorfología del Salar de Atacama y estratigrafía de su núcleo y delta, Segunda Región de Antofagasta, Chile. Undergraduate thesis (unpublished). Universidad Católica del Norte, Antofagasta, 284 p.
- Borda, L.G., Franco, M.G., Córdoba, F., García, M.G., 2016. Geoquímica del Li y As en el salar de Olaroz, Puna de Jujuy. Resultados preliminares. 4th Reunión Argentina de Geoquímica de la Superficie (IV RAGSU). Actas de Resúmenes, 159.
- Boschetti, T., Cortecchi, G., Barbieri, M., Mussi, M., 2007. New and past geochemical data on fresh to brine waters of the Salar de Atacama and Andean Altiplano, northern Chile. *Geofluids.* 7, 33-50.
- Boutt, D.F., Hynek, S.A., Munk, L.A., Corenthal, L.G., 2016. Rapid recharge of fresh water to the halite-hosted brined aquifer of Salar de Atacama, Chile. *Hydrological Processes.* doi:10.1002/hyp.10994.
- Brackebusch, L., 1883. Estudios sobre la Formación Petrolífera de Jujuy. *Boletín de la Academia Nacional de Ciencias de Córdoba.* 5, 137-252.
- Brackebusch, L., 1891. Mapa geológico del interior de la República Argentina, escala 1:1.000.000. Gotha.

- Canavan, R.R., Carrapa, B., Clementz, M.T., Quade, J., DeCelles, P., Schoenbohm, L.M., 2014. Early Cenozoic uplift of the Puna Plateau, Central Andes, based on stable isotope paleoaltimetry of hydrated volcanic glass. *Geology*. 42 (5), 447-450. doi:10.1130/G35239.1.
- Catalano, L.R., 1964. Boro-Berilio-Litio (una nueva fuente natural de energía). Servicio Nacional Geológico Minero. Ministerio De Economía de la Nación Argentina, Buenos Aires, 99 p.
- Carmona, V., Pueyo, J.J., Taberner, C., Chong, G., Thirlwall M., 2000. Solute inputs in the Salar de Atacama (N. Chile). *J. of Geochem. Explor.* 69-70, 449-452.
- Clark, F.W., 1924. The data of geochemistry, fifth ed. U.S. Geol. Survey Bull. 770, 841 p.
- COCHILCO, 2013. Compilación de informes sobre Mercado internacional del litio y potencial del litio en salares del norte de Chile. Comisión Chilena del Cobre y SerNaGeoMin, Secretaría de Minería, Santiago de Chile, 319 p. http://www.cochilco.cl/estudios/info_litio.asp.
- Coira, B., Kay, S.M., Viramonte J., 1993. Upper Cenozoic magmatic evolution of the Argentine Puna - A model for changing subduction geometry. *International Geology Review*. 35 (8), 677-720.
- Corenthal, L.G., Boutt, D.F., Hynek, S.A., Munk, L.A., 2016. Regional groundwater flow and accumulation of a massive evaporate deposit at the margin of the Chilean Altiplano. *Geophysical Research Letters*. 43 (15), 8017-8025.
- Crespo, P., Palma, H., Quintanilla, J., Quispe, L., 1987. Tratamiento químico de salmueras del Salar de Uyuni, Potosí. UMSa-ORSTOM, Informe 7.
- Davis, J., Friedman, I., Gleason, J., 1986. Origin of the lithium-rich brine, Clayton Valley, Nevada. *U.S. Geol. Surv. Bull.* 1622, 131-138.

- Dingman, R.J., 1967. Geology and ground-water resources of the northern part of the Salar de Atacama, Antofagasta Province, Chile. U.S. Geological Survey Bulletin. 1219.
- Durán Iriza, R.J., 2012. Modelación numérica y su contribución al estudio del comportamiento hidrogeológico del sector SW del acuífero del Salar de Atacama, II Región de Antofagasta, Chile. Msc Thesis. Universidad de Chile, Facultad de Ciencias Físicas y Matemáticas, 201 p.
- Egenhoff, S.O., Lucassen, F., 2003. Chemical and isotopic composition of lower to upper Ordovician sedimentary rocks (Central Andes /South Bolivia): implications for their source. *Journal of Geology*. 111, 487-497.
- Ericksen, G.E., 1961. Rhyolite tuff, a source of the salts of northern Chile. *Geol. Survey Research*. U.S. Geological Survey Professional Paper. 424, C224-C225.
- Ericksen, G.E., 1963. Geology of the salt deposits and the salt industry of northern Chile. U.S. Geological Survey. Open-File Report, 164 p.
- Ericksen, G.E., Chong, G., Vila, T., 1976a. Lithium resources of salars in the central Andes. U.S. Geological Survey Professional Paper. 1005, 66-74.
- Ericksen, G., Chong, G., Vila, T., 1976b. Lithium resources of salars in the central Andes, in: Vine, J.D., (Ed.), *Lithium Resources and Requirements by the Year 2000*. U.S. Geological Survey Professional Paper. 1005, 66-74.
- Ericksen, G.E., Vine, J.D., Ballon, R., 1977. Lithium-rich brines at Salar de Uyuni and nearby salars in southwestern Bolivia. U.S. Geological Survey. Open-File Repository. 77-615, 52 p.
- Ericksen, G.E., Salas, R., 1977. Geology and resources of salars in the central Andes. U.S. Geological Survey. Open File Repository. 88-210, 51 p.

- Ericksen, G.E., Vine, J.D., Ballon, R.A., 1978. Chemical composition and distribution of lithium-rich brines in salar de Uyuni and nearby salars in southwestern Bolivia. *Energy*. 3 (3), 355-363.
- Ericksen, G.E., Salas, R., 1987. Geology and resources of salars in the central Andes. U.S. Geological Survey. Open File Repository. 88-210, 51 p.
- Eugster, H.P., 1980. Geochemistry of evaporitic lacustrine deposits. *Ann. Rev. Earth Planet Sciences*. 8, 35-63.
- Franco, M.G., Borda, L., García, M.G., López Steinmetz, R.L., Flores, P., Córdoba, F., 2016. Geochemical and sedimentological characterization of the Salar de Olaroz, northern Argentinean Puna, Central Andes. 3rd International Workshop on Lithium, Industrial Minerals and Energy, Jujuy, Argentina.
- Franco, M.G., Peralta Arnold, Y.J., Santamaría, C.D., López Steinmetz, R.L., Tassi, F., Venturi, S., Jofré, C.B., Caffè, P.J., Córdoba, F.E., 2020. Chemical and isotopic features of Li-rich brines from the Salar de Olaroz, Central Andes of NW Argentina, 2020. *Journal of South American Earth Sciences*. 103, 10742. doi:10.1016/j.jsames.2020.102742.
- Garcés, I., López, P.L., Agué, L.F., Chong, G., Vallès, V., Gimeno, M.J., 1996. Características geoquímicas generales del sistema salino del Salar de Llamara (Chile). *Estudios Geológicos*. 52, 23-35.
- García, M.G., Borda, L.G., Godfrey, L.V., López Steinmetz, R.L., Losada Calderón, A., 2019. Characterization of lithium cycling in the Salar de Olaroz, Central Andes, using a geochemical and isotopic approach. *Chemical Geology*. 531, 119340. doi:10.1016/j.chemgeo.2019.119340.
- García-Castellanos, D., 2006. Long-term evolution of tectonic lakes: Climatic controls on the development of internally drained basins, in: Willett, S.D., Hovius, N., Brandon, M.T., Fisher, D.M., (Eds.), *Tectonics, Climate, and Landscape Evolution*. Geological Society of

- America Special Paper, 398. Penrose Conference Series, 283-294.
doi:10.1130/2006.2398(17).
- Garziona, C.N., Hoke, G.D., Libarkin, J.C., Withers, S., MacFadden, B., Eiler, J., Ghosh, P., Mulch, A., 2008. Rise of the Andes. *Sciences*. 320 (5881), 1304-1307.
doi:10.1126/science.1148615.
- Garziona, C.N., McQuarrie, N., Perez, N.D., Ehlers, T.A., Beck, S.L., Kar, N., Eichelberger, Chapman, A.D., Ward, K.M., Ducea, M.N., Lease, R.O., Poulsen, C.J., Wagner, L.S., Saylor, J.E., Zandt, G., Horton, B.K., 2017. Tectonic Evolution of the Central Andean Plateau and Implications for the Growth of Plateaus. *Annual Review of Earth and Planetary Sciences*. 45, 29-59.
- Garreaud, R.D., 2009. The Andes climate and weather. *Adv. in Geosci.* 22, 3-11.
- Garrett, D.E., 2004. Handbook of lithium and natural calcium chloride: their deposits, processing, uses and properties, first ed. Elsevier Academic Press.
- Gianni, G.M., Dávila, F., Echaurren, A., Fennell, L., Tobal, J., Navarrete, C.R., Quezada, P., Folguera, A., Giménez, M., 2018. A geodynamic model linking Cretaceous orogeny, arc migration, foreland basin subsidence and marine ingression in southern South America. *Earth-Science Reviews* 185, 437-462. doi:10.1016/j.earscirev.2018.06.016.
- Godfrey, L.V., Chan, L. H., Alonso, R.N., Lowenstein, T.K., McDonough, W.F., Houston, J., Li, J., Bobst, A., Jordan, T.E., 2013. The role of climate in the accumulation of lithium-rich brine in the Central Andes. *Applied Geochemistry*. 38, 92-102.
- Godfrey, L., Alvarez-Amado, F., 2020. Volcanic and saline lithium input to the Salar de Atacama. *Minerals*. 10, 201. doi:10.3390/min10020201.
- Götze, H.-J., Krause, S., 2002. The Central Andean gravity high, a relic of an old subduction complex? *Journal of South American Earth Sciences*. 14, 799-811.

- Gruber, P., Medina, P., 2010. Global lithium availability: a constraint for electric vehicles? Master thesis, University of Michigan, 76 p.
- Hardie, L., Eugster, H., 1970. The evolution of closed-basin brines. Fiftieth Anniversary Symposia, Mineralogy and Geochemistry of Non-Marine Evaporites. Mineralogical Society of America Special Publication. 273-290.
- Helvacı, C., Mordogan, H., Çolak, M., Gündogan, I., 2004, Presence and distribution of lithium in borate deposits and some recent lake waters of west-central Turkey. *International Geology Review*. 46, 177-190. doi:10.2747/0020-7179.46.2.177.
- Herail, G., Oller, J., Baby, P., Bonhomme, M., Soler, P., 1996. Strike-slip faulting, thrusting and related basins in the Cenozoic evolution of the southern branch of the Bolivian Orocline. *Tectonophysics*. 259, 201-212.
- Hilley, G.E., Strecker, M.R., 2005. Processes of oscillatory basin filling and excavation in a tectonically active orogen: Quebrada del Toro basin, NW Argentina. *Geological Society of America Bulletin*. 117, 887-901. doi:10.1130/B25602.1.
- Hongn, F.D., Del Papa, C., Powell, T., Petrinovic, I., Mon, R., Deraco, V., 2007. Middle Eocene deformation and sedimentation in the Puna-Eastern Cordillera transition (23°-26°S): control by preexisting heterogeneities on the pattern of initial Andean shortening. *Geology*. 35, 271-274. doi:10.1130/G23189A.1.
- Houston, J., Butcher, A., Ehren, P., Evans, K., Godfrey, L., 2011. The evaluation of brine prospects and the requirement for modifications to filing standards. *Economic Geology*. 106, 1225-1239.
- Ide, F., Kunasz, I.A., 1989. Origin of lithium in Salar de Atacama, northern Chile, in: Ericken, G.E., Cañas Pinochet, M.T., Reinemund, J.A. (Eds.), *Geology of the Andes and its relation to hydrocarbon and mineral resources*. Circum-Pacific Council for Energy and Mineral Resources Earth Science Series, 11, pp. 165-172.

- Isacks, B., 1988. Uplift of the Central Andean Plateau and bending of the Bolivian orocline. *Journal of Geophysical Research: Solid Earth*. 93, 3211-3231. doi:10.1029/JB093iB04p03211.
- Jordan, T.E., Nester, P.L., Blanco, N., Hoke, G.D., Dávila, F., Tomlinson, A.J., 2010. Uplift of the Altiplano-Puna plateau: A view from the west. *Tectonics*. 29, TC5007. doi:10.1029/2010TC002661.
- Kaseman, S.A., Meixner, A., Erzinger, J., Viramonte, J.G., Alonso, R.N., Franz, G., 2004. Boron isotope composition of the geothermal fluids and borate minerals from salar deposits (central Andes/NW Argentina). *Journal of South American Earth Sciences*. 16 (8), 685-697. doi:10.1016/j.jsames.2003.12.004.
- Kay, S.M., Coira, B., Viramonte, J., 1994. Young mafic back arc volcanic rocks as indicators of continental lithospheric delamination beneath the Argentine Puna plateau, central Andes. *Journal of Geophysical Research: Solid Earth*. 99 (B12), 24323-24339.
- Kesler, S.E., Gruber, P.W., Medina, F.A., Keoleian, G.A., Everson, M.P., Wallington, T.J., 2012. Global lithium resources: relative importance of pegmatites, brine and other deposits. *Ore Geology Review*. 48, 55-69.
- Kistler, R.B., Helvacı, C., 1974. Boron and Borates. In: Carr DD (Ed.) *Industrial Minerals and Rocks*. Society of Mining, Metallurgy and Exploration. 6th Edition, 171-186.
- Kunasz, I.A., 1976. Lithium resources - prospects for the future. In: Vine JD (Ed.) *Lithium Resources and Requirements by the Year 2000*. U.S. Geological Survey Professional Paper. 1005, 26-30.
- Kunasz, I.A., 2006. Lithium resources, in: Kogel, J.E., Trivedi, N.C., Barker, J.M., Krukowski, S.T. (Eds.), *Industrial minerals and rocks, commodities, markets and uses*. Society for Mining, Metallurgy, and Exploration.

- Langbein, W.B., 1961. Salinity and hydrology of closed lakes. U.S. Geological Survey Professional Paper. 412, 20 p.
- Li, X., Mo, Y., Qing, W., Shao, S., Tang, C.Y., Li, J., 2019a. Membrane-based technologies for lithium recovery from water lithium resources: A review. *Journal of Membrane Science*. 591. doi:10.1016/j.memsci.2019.117317.
- Li, Q., Fan, Q., Wang, J., Qin, J., Zhang, X., Wei, H., Du, Y., Shan, F., 2019b. Hydrochemistry, distribution and formation of lithium-rich brines in salt lakes on the Qinghai-Tibetan Plateau. *Minerals*. 9, 528. doi:10.3390/min905528.
- López, P.L., Auqué, L.F., Garcés, I., Chong, G., Vallès, V., Gimeno, M.J., 1996. Aplicaciones de la modelización geoquímica al estudio de pautas evolutivas en las salmueras del Salar de Llamara (Chile). Aproximación de método inverso. *Estudios Geológicos*. 52, 197-209.
- López Julián, P.L., Garcés Millás, I.M., 2001. Relaciones geoquímicas entre los distintos tipos de aguas superficiales del salar de Surire (Chile). Departamento Ciencias de la Tierra, Universidad de Zaragoza, 10 p.
- López Steinmetz, R.L., 2017. Lithium- and boron-bearing brines in the Central Andes: exploring hydrofacies on the eastern Puna plateau between 23° and 23°30'S. *Mineralium Deposita*. 52, 35-50.
- López Steinmetz, R.L., Galli, C.I., 2015. Hydrological change during the Pleistocene-Holocene transition associated with the Last Glacial Maximum-Altithermal in the eastern border of northern Puna. *Andean Geology*. 42 (1), 1-19.
- López Steinmetz, R.L., Fong, S.B., 2019. Water legislation in the context of lithium mining in Argentina. *Resources Policy*, 64, 101510. doi:10.1016/j.resourpol.2019.101510.
- López Steinmetz, R.L., Montero-López, C., 2019. Stratigraphy and sedimentary environments of the Villa María and Peña Colorada formations (Paleogene), westernmost Argentine plateau. *Latin American Journal of Sedimentology and Basin Analysis*. 26 (1), 39-56.

- López Steinmetz, R.L., Salvi, S., García, M.G., Béziat, D., Franco, G., Constantini, O., Córdoba, F., Caffè, P.J., 2018. Northern Puna plateau-scale survey of Li brine-type deposits in the Andes of NW Argentina. *Journal of Geochemical Exploration*. 190, 26-38.
- López Steinmetz, R.L., Salvi, S., Sarchi, C., Santamans, C., López Steinmetz, L.C., 2020a. Lithium and brine geochemistry in the salars of the Southern Puna, Andean plateau of Argentina. *Economic Geology*. 115 (5), 1079-1096. doi:10.5382/econgeo.4754.
- López Steinmetz, R.L., Avila, P., Dávila, F., 2020b. Landscape and drainage evolution during the Cenozoic in the Salinas Grandes Basin, Andean Plateau of NW Argentina. *Geomorphology*. 353, 107032. doi:10.1016/j.geomorph.2020.107032.
- López Steinmetz, R.L., Avila, P., Dávila, F., 2020c. Landscape and drainage evolution during the Cenozoic in the Salinas Grandes Basin, Andean Plateau of NW Argentina. *Geomorphology*. 353, 107032. doi:10.1016/j.geomorph.2020.107032.
- Lowenstein, T., Risacher, F., 2009. Closed basin brine evolution and the influence of Ca-Cl inflow waters. Death Valley and Bristol Dry Lake, California, Qaidam Basin, China, and Salar de Atacama, Chile. *Aquat. Geochem.* 15, 71-94.
- Mardones, L., 1986. Características geológicas e hidrogeológicas del Salar de Atacama. In Lagos, G. (Ed.), *El litio: Un nuevo recurso para Chile*. Universidad de Chile, Santiago, Chile, pp. 181-216.
- Mardones, L., Chong, G., 1991. Consecuencias hidrológicas de la explotación del Salar de Atacama, Norte de Chile. 6th Congreso Geológico Chileno. Resúmenes expandidos, 719-722.
- Maro, G., Caffè, P.J., Báez, W., 2017. Volcanismo monogenético máfico cenozoico de la Puna. 20th Congreso Geológico Argentino, Relatorio, 548-577.
- McQuarrie, N., 2002. The kinematic history of the Central Andean fold-thrust belt, Bolivia: implications for building a high plateau. *GSA Bulletin*. 114 (8), 950-963.

- Meixner, A., Sarchi, C., Lucassen, F., Becchio, R., Caffè, P.J., Lindsay, J., Rosner, M., Kasemann, S.A., 2019. Lithium concentrations and isotope signatures of Palaeozoic basement rocks and Cenozoic volcanic rocks from the Central Andean arc and back-arc. *Mineralium Deposita*. doi:10.1007/s00126-019-00915-2.
- Melvin, J.L., 1991. *Evaporites, Petroleum and Mineral Resources*. Developments in Sedimentology, fiftieth ed. Elsevier, 556 p.
- Mohr, S., Mudd, G., Giurco, D., 2010. *Lithium Resources and Production: a critical global assessment*. Prepared for CSIRO Minerals Down Under Flagship, by the Institute for Sustainable Futures, University of Technology, Sydney, and Department of Civil Engineering, Monash University. Final Report, 107 p.
- Montero-López, C., Hongn, F., López Steinmetz, P.L., Aramayo, A., Pingel, H., Strecker, M.R., Cottle, J.M., Bianchi, C., 2020. Development of an incipient Paleogene topography between the present-day eastern andean plateau (Puna) and the Eastern Cordillera, southern Central Andes, NW Argentina. *Basin Research*. doi:10.1111/bre.12510.
- Moraga, B.A., Chong, D.G., Forttz, M.A., Henriquez, A.H., 1974. Estudio geológico del Salar de Atacama, Provincia de Antofagasta. Instituto de Investigaciones Geológicas Boliviano. 29, 56 p.
- Mpodozis, C., Ramos, V., 1989. The Andes of Chile and Argentina. In: Ericksen, G., Cañas-Pinochet, M., Reinemund, J. (Eds.), *Geology of the Andes and its Relation to Hydrocarbon and Mineral Resources*, Circum-Pacific Council for Energy and Mineral Resources Earth Sciences Series. 11, 59-90.
- Munk, L.A., Hynek, S.A., Bradley, D., Boutt, D., Labay, K., Jochens, H., 2016. Lithium brines: A Global Perspective. *Reviews in Economic Geology*. 18, 339-365.

- Munk, L.A., Boutt, D.F., Hynek, S.A., Moran, B.J., 2018. Hydrogeochemical fluxes and processes contributing to the formation of lithium-enriched brines in a hyper-arid continental basin. *Chemical Geology*. 493, 37-57.
- Muñoz, N., Charrier, R., 1996. Uplift of the western border of the Altiplano on a west-vergent thrust system, northern Chile. *Journal of South American Earth Sciences*. 9, 171-181.
- Orberger, B., Rojas, W., Millot, R., Flehoc, C., 2015. Stable isotopes (Li, O, H) combined with chemistry: powerful tracers for Li origins in Salar deposits from the Puna region, Argentina. *Procedia Earth and Planetary Science*. 13, 307-311.
- Ovejero Toledo, A., Alonso, R.N., Ruiz, T., Quiroga, A.G., 2009. Evapofacies halítica en el Salar del Rincón, Departamento Los Andes, Salta. *Revista de la Asociación Geológica Argentina*. 64 (3), 493-500.
- Paola, C., Kyle, S., Mohrig, D., Reinhardt, L., 2009. The “unreasonable effectiveness” of stratigraphic and geomorphic experiments. *Earth-Science Reviews*. 97, 1-43. doi:10.1016/j.earscirev.2009.05.003.
- Peralta Arnold, Y.J., Cabssi, J., Tassi, F., Caffè, J.P., Vaselli, O., 2017. Fluid geochemistry of a deep-seated geothermal resource in the Puna plateau (Jujuy Province, Argentina). *Journal of Volcanology and Geothermal Research*. doi:10.1016/j.jvolgeores.2017.03.030.
- Ramos, V., Cristallini, F., Pérez, D., 2002. The Pampean flat-slab of the Central Andes. *Journal of South American Earth Sciences*. 15, 59-78.
- Rettig, S.L., Jones, B.F., Risacher, F., 1987. Geochemical evolution of brines in the Salar de Uyuni, Bolivia. *Chemical Geology*. 30, 57-79.
- Riley, J.P., Tongudai, M., 1964. The lithium content of sea water. *Deep Sea Research and Oceanographic Abstracts*. 11 (4), 563-568. doi:10.1016/0011-7471(64)90002-6.
- Risacher, F., Fritz, B., 1991. Quaternary geochemical evolution of the Salar of Uyuni and Coipasa, Central Altiplano, Bolivia. *Chemical Geology*. 90, 211-231.

- Risacher, F., Alonso, H., 1996. Geoquímica del Salar de Atacama, parte 2: evolución de las aguas. *Revista Geológica de Chile*. 23 (2), 123-134.
- Risacher, F., Alonso, H., Salazar, C., 1999. Geoquímica de aguas en cuencas cerradas: I, II y III Regiones – Chile. Convenio de Cooperación Dirección General de Aguas de Chile, Universidad Católica del Norte, Institut de Recherche pour le Developpement. Report 51, 781 p.
- Risacher, F., Fritz, B., 2000. Bromine geochemistry of Salar de Uyuni and deeper salt crusts, Central Altiplano, Bolivia. *Chemical Geology*. 167, 373-397.
- Risacher, F., Alonso, H., Salazar, C., 2002. Hydrochemistry of two adjacent saline lakes in the Andes of northern Chile. *Chemical Geology*. 187, 53-57.
- Risacher, F., Alonso, H., Salazar, C., 2003. The origin of brines and salts in Chilean Salars: a hydrochemical review. *Earth-Science Reviews*. 65, 249-292.
- Risacher, F., Fritz, B., 2009. Origin of salt and brine evolution of Bolivian and Chilean Salars. *Aquat. Geochemistry*. 15, 123-157.
- Ruetenik, G.A., Hoke, G.D., Moucha, R., Val, P., 2018. Regional landscape response to thrust belt dynamics: The Iglesia basin, Argentina. *Basin Research*. 30. doi:10.1111/bre.12295.
- Salas, J., Aravena, R., Guzmán, E., Comellà, O., Guimerà, J., Tore, C., Von Igel, W., Fock, A., Henríquez, A., 2009. Modelo de evolución hidroquímica e isotópica en el sistema de recarga del Salar de Atacama a través de su margen E. 12th Congreso Geológico Chileno, 1-4.
- Scandiffio, G., Alvarez, M., 1990. Informe geoquímico sobre la zona geotérmica de Laguna Colorada, Bolivia. Geothermal investigations with isotope and geochemical techniques in Latin American. Proc. of a Final Res. Co-ordination Meeting, Organismo Internacional de Energía Atómica, Costa Rica, 77-113.

- Scandiffio, G., Rodríguez, J., 1990. Geochemical report on the Sajama geothermal area, Bolivia. Geothermal investigations with isotope and geochemical techniques in Latin American. Proc of a Final Res Co-ordination Meeting, Organismo Internacional de Energía Atómica, Costa Rica, 114-168.
- Schmidt, N., 2010. Hydrological and hydrochemical investigations at the Salar de Uyuni (Bolivia) with regard to the extraction of lithium. FOG. 26.
- Schurr, B., Asch, G., Rietbrock, A., Kind, R., Pardo, M., Heit, B., Monfret, T., 1999. Seismicity and average velocities beneath the Argentine Puna plateau. Geophysical Research Letters. 26 (19), 3025-3028.
- Scott, E.M., Allen, M.B., Macpherson, C.G., McCaffrey, K.J.W., Davidson, J.P., Saville, C., Ducea, M.N., 2018. Andean surface uplift constrained by radiogenic isotopes of arc lavas. Nature Communications. 9, 969. doi:10.1038/s41467-018-03173-4.
- Sempere, T., Butler, R.F., Richards, D.F., Marshall, L.G., Sharp, W. y Swisher, C.C. 1997. Stratigraphy and chronology of Upper Cretaceous-lower Paleogene strata in Bolivia and northwest Argentina. Bulletin of Geological Society of America. 109 (6), 709-727.
- Sobel, E.R., Hilley, G.E., Streeter, M.R., 2003. Formation of internally drained contractional basins by aridity-limited bedrock incision. Journal of Geophysical Research. 108. doi:10.1029/2002JB001683.
- Stoertz, G.E., Ericksen, G.E., 1974. Geology of salars in northern Chile. U.S. Geological Survey Professional Paper. 811, 65 p.
- Tassara, A., 2005. Interaction between the Nazca and South American plates and formation of the Altiplano–Puna plateau: Review of a flexural analysis along the Andean margin (15°–34°S). Tectonophysics. 399, 39-57. doi:10.1016/j.tecto.2004.12.014.
- Teng, F.-Z., McDonough, W.F., Rudnick, R.L., Dalpé, C., Tomascak, P.B., Chapell, B.W., Gao, S., 2004. Lithium isotopic composition and concentration of the upper continental

- crust. *Geochimica et Cosmochimica Acta*. 68 (20), 4167-4178. doi: 10.1016/j.gca.2004.03.031.
- Tremblay, M.M., Fox, M., Schmidt, J.L., Tripathy-Lang, A., Wielicki, M.M., Harrison, T.M., Zeitler, P.K., Shuster, D.L., 2015. Erosion in southern Tibet shut down at ~10 Ma due to enhanced rock uplift within the Himalaya. *Proceedings of the National Academy of Sciences of the United States of America*. 112. doi: 10.1073/pnas.1515652112.
- Turner, J.C., 1959. Estratigrafía del cordón de Escaya y de la Sierra de Rinconada (Jujuy). *Revista de la Asociación Geológica Argentina*. 13 (1-2), 15-29.
- Vandervoort, D., Jordan, T., Zeitler, P., Alonso, R.N., 1995. Chronology of internal drainage development and uplift, southern Puna plateau, Argentina Central Andes. *Geology*. 23, 145-148. doi:10.1130/0091-7613(1995)023<0145:CCDDA>2.3.CO;2.
- Vásquez, C., Ortíz, C., Suárez, F., Muñoz, J.F., 2013. Modeling flow and reactive transport to explain mineral zoning in the Atacama salt flat aquifer, Chile. *Journal of Hydrology*. 490, 114-125.
- Vila, T., 1975. Geología de los depósitos salinos andinos, Provincia de Antofagasta, Chile. *Revista Geológica de Chile*. 2, 41-55.
- Vinante, D., Alonso, R.N., 2006. Evapofacies del Salar del Hombre Muerto, Puna Argentina: distribución y génesis. *Revista de la Asociación Geológica Argentina*. 61 (2), 286-297.
- Vine, J.D., 1976. Lithium Resources and Requirements by the Year 2000. U.S. Geological Survey Professional Paper. 1005, 169 p.
- Warren, J.K., 2010. Evaporites through time: Tectonic, climatic and eustatic controls in marine and non-marine deposits. *Earth-Science Reviews*. 98, 217-268. doi:10.1016/j.earscirev.2009.11.004.
- Weissman, G.S., Hartley, A.J., Scuderi, L.A., Nichols, G.J., Owen, A., Wright, S., Felicia, A.L., Holland, F., Anaya, F.M.L., 2015. Fluvial geomorphic elements in modern

- sedimentary basins and their potential preservation in the rock record: A review. *Geomorphology*. 250, 187-219. doi:10.1016/j.geomorph.2015.09.005.
- Whitman, D., Isacks, B.L., Kay, S.M., 1996. Lithospheric structure and along-strike segmentation of the Central Andean Plateau: seismic Q, magmatism, flexure, topography and tectonics. *Tectonophysics*. 259 (1-3), 29-40. doi:10.1016/0040-1951(95)00130-1.
- Yu, J.Q., Gao, C.L., Cheng, A.Y., Liu, Y., Zhang, Y., He, X.H., 2013. Geomorphic, hydroclimatic and hydrothermal controls on the formation of lithium brine deposits in the Qaidam Basin, northern Tibetan Plateau, China. *Ore Geology Reviews*. 50, 171-183. doi:10.1016/j.oregeorev.2012.11.001.
- Zheng, M., Liu, X., 2009. Hydrochemistry of Salt Lakes of the Qinghai-Tibet Plateau, China. *Aquatic Geochemistry*. 15, 293-320. doi:10.1007/s10498-008-9055-y.

Table 1. Altitude and comparative areal surfaces of Andean salt pans and of their endorheic basin catchments.

N° (Fig. 1)	Salt pan	Altitude (m asl)	Salt pan surface (km ²)	Basin surface (km ²)
1	Surire	4,260	144	574
2	Coipasa	3,656	1,650	29,817
3	Uyuni	3,633	10,000	45,239
4	Empexa	3,725	402	2,111
5	Huasco	3,778	51	1,572
6	Coposa	3,730	85	1,116
7	Michincha	4,130	25	282
8	Alconcha	4,250	4	128
9	Carcote	3,690	108	561
10	Ascotan	3,716	243	1,757
11	Pastos Grandes (Altiplano)	4,437	124	660
12	Atacama	2,300	3,000	18,100
13	El Tara	4,330	48	2,035

14	Aguas Calientes Norte o 1	4,280	15	281
15	Pujsa	4,500	18	634
16	Loyoques o Quisquiro	4,150	80	676
17	Aguas Calientes Centro o 2	4,200	134	1,168
18	El Laco	4,250	16	306
19	Aguas Calientes Sur o 3	3,950	46	476
20	Capur	3,950	27	137
21	Imilac	2,949	10	189
22	Punta Negra	2,945	250	4,253
23	Aguas Calientes Sur Sur o 4	3,665	20	656
24	Pajanoles	3,537	104	1,984
25	La Azufrera	3,580	3	214
26	Gorbea	3,950	27	324
27	Ignorados	4,250	1	38
28	Agua Amarga	3,550	23	863
29	Aguilar	3,220	71	589
30	La Isla	3,950	152	858
31	Los Infieles	3,520	7	293
32	Las Parinas	3,987	40	676
33	Salar Grande	3,950	29	867
34	Pedernales	3,370	335	3,620
35	Salar de la Laguna	3,494	1	400
36	La Piedra Parada	4,150	28	388
37	Wheelwright	4,220	6	466
38	Maricunga	3,760	145	3,045
39	Incahuasi	3,269	18	1,620
40	Antofalla-Botijuelas	3,330	655	9,259
41	Río Grande	3,668	56	1,155
42	Arizaro	3,474	1,708	7,508
43	Hombre Muerto	3,970	300	3,881
44	Diablillos	4,032	4	481
45	Ratones	3,822	3	605
46	Centenario	3,816	7	1,044
47	Pocitos-Quirón	3,663	450	2,969
48	Pozuelos	3,663	75	367
49	Pastos Grandes (Puna)	3,780	27	1,752

50	Rincón	3,725	250	3,017
51	Cauchari	3,903	80	2,557
52	Olaroz	3,903	130	2,519
53	Jama	4,080	25	1,500
54	Salinas Granes	3,410	280	5,529
55	Guayatayoc	3,400	140	11,805

Table 2. Chemical composition of brines from Andean salt pans. Hydrochemical data of the Altiplano salars correspond to values reported by Risacher and Fritz (1991), excepting for samples Uyu0, C0, EMP, and PGB that are from Ericksen and Salas (1987). Summarized data for the Puna de Atacama salars follow Risacher et al. (1992) summarized by COCHILCO, (2013), excepting for samples LAC0, SUR0, HCO0, ASC0, ATA0, ATAdo, and AZU0 that are from Ericksen and Salas (1987). Brine chemistry of the Puna salt pans follows data reported by López Steinmetz (2017), López Steinmetz et al. (2018), and López Steinmetz et al. (2020a), excepting for samples CE0, HMC0, R30, AR0, PC0, RI0, and RG0 that are from Ericksen and Salas (1987). TDS in g L^{-1} , remaining concentrations in mg L^{-1} .

	g L ⁻¹	mg L ⁻¹									
UYUNI											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
uyu0	351	261	11,800	94,900	13,500	700	191,800	13,200	-	592	1,136
UA15	121	545	7,780	107,000	9,380	412	190,000	9,550	-	-	302
UA80	122	310	16,100	91,800	17,600	770	190,000	23,000	-	-	669
UA200	123	316	16,600	90,300	17,300	812	191,000	22,400	-	-	655
UA400	123	327	16,800	94,900	17,400	812	196,000	22,500	-	-	657
UA600	123	315	17,300	91,400	17,600	826	192,000	24,400	-	-	668
UB10	125	137	38,400	57,000	29,700	1,780	200,000	43,900	-	-	1,710
UB100	224	149	51,000	36,100	19,400	2,560	210,000	32,800	-	-	2,020
UB250	125	50	55,400	28,800	19,400	2,790	214,000	34,300	-	-	2,160
UB400	125	50	55,900	29,200	19,700	2,830	215,000	34,600	-	-	2,190

UC5	123	233	32,3 00	68,30 0	20,10 0	1,46 0	194,0 00	30,70 0	-	-	1,23 0
UC100	122	268	19,2 00	88,60 0	19,00 0	888	190,0 00	25,60 0	-	-	843
UC250	122	269	19,3 00	88,60 0	18,60 0	868	192,0 00	26,20 0	-	-	871
UC400	122	269	19,2 00	89,20 0	18,80 0	881	191,0 00	26,70 0	-	-	970
UD10	122	208	30,6 00	66,20 0	26,70 0	1,31 0	197,0 00	30,80 0	-	-	1,24 0
UD100	122	317	19,9 00	85,10 0	21,60 0	888	194,0 00	22,60 0	-	-	864
UD250	122	293	19,2 00	87,60 0	20,30 0	819	193,0 00	25,30 0	-	-	864
UD400	122	294	19,3 00	88,10 0	20,30 0	819	191,0 00	25,40 0	-	-	871
UE5	123	294	24,5 00	78,70 0	22,60 0	708	195,0 00	27,70 0	-	-	987
UE100	122	269	17,6 00	92,00 0	19,30 0	708	190,0 00	29,40 0	-	-	871
UE250	122	269	17,4 00	92,20 0	19,30 0	708	190,0 00	28,60 0	-	-	859
UE400	122	269	17,3 00	92,00 0	19,30 0	708	189,0 00	28,10 0	-	-	860
UF30	121	654	7,39 0	109,0 00	7,430	339	190,0 00	10,30 0	-	-	239
UF110	121	618	7,63 0	108,0 00	7,510	339	190,0 00	10,70 0	-	-	232
UG15	121	834	5,78 0	112,0 00	5,790	254	190,0 00	8,200	-	-	171
UG95	121	738	6,39 0	110,0 00	6,180	266	191,0 00	9,140	-	-	199
UG270	121	666	6,97 0	109,0 00	6,800	303	190,0 00	9,790	-	-	233
UH10	121	750	6,93 0	109,0 00	7,190	315	191,0 00	8,960	-	-	236
UH100	121	666	7,85 0	107,0 00	7,940	351	190,0 00	10,10 0	-	-	266
UH300	122	437	11,5 00	100,0 00	10,30 0	463	189,0 00	18,70 0	-	-	372
UH500	122	401	12,1 00	98,20 0	10,50 0	488	189,0 00	20,30 0	-	-	397
UH700	122	391	12,1 00	99,40 0	10,80 0	489	190,0 00	20,70 0	-	-	405
UH900	122	367	12,6 00	100,0 00	11,20 0	513	188,0 00	22,20 0	-	-	423
UI15	121	714	6,66 0	109,0 00	7,120	303	190,0 00	9,370	-	-	226
UI100	121	702	6,63 0	106,0 00	6,760	303	189,0 00	9,360	-	-	214
UI1000	121	569	7,29 0	106,0 00	7,590	303	189,0 00	14,10 0	-	-	261
UJ15	121	786	7,00 0	107,0 00	7,590	339	190,0 00	8,930	-	-	254
UJ100	122	521	11,1	100,0	11,00	584	191,0	14,20	-	-	399

			00	00	0		00	0			
UJ300	122	437	12,8	95,90	12,00	560	189,0	18,10	-	-	437
			00	0	0		00	0			
UJ700	122	391	14,1	94,80	12,40	575	187,0	24,10	-	-	525
			00	0	0		00	0			
UK10	122	622	8,82	103,0	8,880	413	191,0	11,00	-	-	288
			0	00			00	0			
UK100	122	417	14,7	94,30	14,60	685	192,0	18,70	-	-	457
			00	0	0		00	0			
UK200	123	319	15,6	93,80	14,40	688	190,0	25,10	-	-	453
			00	0	0		00	0			
UK400	123	295	15,9	93,80	24,00	688	187,0	28,50	-	-	441
			00	0	0		00	0			
UL20	122	401	17,5	87,60	19,50	805	194,0	16,00	-	-	452
			00	0	0		00	0			
UL100	122	390	17,1	87,90	17,80	805	185,0	16,30	-	-	557
			00	0	0		00	0			
UL250	122	340	18,9	82,80	17,40	840	190,0	18,10	-	-	590
			00	0	0		00	0			
UM17	121	638	6,42	109,0	7,160	277	189,0	7,870	-	-	669
			0	00			00				
UM100	122	425	13,5	91,00	12,00	559	191,0	15,10	-	-	319
			00	0	0		00	0			
UM400	122	269	16,3	92,50	13,90	672	187,0	26,00	-	-	461
			00	0	0		00	0			
UN16	122	354	19,1	85,60	18,00	868	194,0	19,10	-	-	563
			00	0	0		00	0			
UN100	122	354	19,4	85,10	19,40	916	193,0	19,30	-	-	591
			00	0	0		00	0			
UN300	123	245	21,7	80,50	19,40	979	192,0	24,80	-	-	718
			00	0	0		00	0			
UO9	121	523	10,5	103,0	10,80	471	191,0	11,60	-	-	250
			00	00	0		00	0			
UO100	122	342	17,8	89,20	16,60	784	190,0	20,00	-	-	533
			00	0	0		00	0			
UO500	123	234	21,8	88,60	18,30	937	190,0	36,00	-	-	892
			00	0	0		00	0			
UP17	122	378	16,7	82,60	16,30	756	192,0	17,10	-	-	486
			00	0	0		00	0			
UP100	122	305	20,6	78,20	19,40	930	193,0	21,00	-	-	662
			00	0	0		00	0			
UP500	123	282	21,3	77,30	19,00	944	193,0	24,00	-	-	770
			00	0	0		00	0			
UQ17	120	577	7,29	111,0	7,510	313	190,0	9,020	-	-	141
			0	00			00				
UQ100	121	533	9,40	104,0	9,460	399	190,0	10,90	-	-	232
			0	00			00	0			
UQ450	121	545	9,96	101,0	9,660	411	192,0	11,70	-	-	241
			0	00			00	0			
UQ800	121	509	10,4	98,20	10,00	424	190,0	12,80	-	-	202
			00	0	0		00	0			
UR15	121	457	5,69	112,0	5,470	217	190,0	8,090	-	-	639
			0	00			00				
UR100	121	565	8,09	107,0	7,980	314	190,0	10,80	-	-	101
			0	00			00	0			

UR450	121	577	8,31 0	106,0 00	8,330	338	188,0 00	11,20 0	-	-	134
UR800	122	413	12,5 00	102,0 00	11,30 0	413	187,0 00	19,70 0	-	-	482
US9	120	577	6,34 0	108,0 00	6,650	276	190,0 00	8,870	-	-	164
US100	121	606	7,63 0	106,0 00	7,980	314	192,0 00	10,50 0	-	-	195
US450	122	401	11,2 00	99,40 0	12,00 0	389	187,0 00	21,60 0	-	-	494
US00	122	294	13,5 00	101,0 00	14,00 0	465	186,0 00	30,30 0	-	-	785
UT15	121	642	6,83 0	109,0 00	7,470	278	190,0 00	10,10 0	-	-	198
UT100	120	626	6,97 0	107,0 00	7,350	277	189,0 00	10,20 0	-	-	197
UT450	121	630	6,90 0	106,0 00	7,230	266	190,0 00	10,20 0	-	-	195
UT800	121	533	8,31 0	106,0 00	8,800	327	189,0 00	13,00 0	-	-	244
UU20	121	565	10,3 00	106,0 00	6,650	350	188,0 00	12,30 0	-	-	273
UU350	120	533	8,97 0	103,0 00	7,590	291	191,0 00	11,80 0	-	-	275
UU700	121	388	10,8 00	107,0 00	5,580	316	188,0 00	19,20 0	-	-	328
UV10	121	630	8,14 0	110,0 00	6,450	242	191,0 00	10,10 0	-	-	235
UV100	121	618	8,02 0	110,0 00	6,490	242	190,0 00	10,60 0	-	-	244
UV500	121	618	8,02 0	108,0 00	6,370	242	191,0 00	10,70 0	-	-	226
UW22	123	480	27,7 00	69,90 0	22,80 0	1,03 0	200,0 00	18,80 0	-	-	1,08 0
UW100	123	453	20,9 00	86,30 0	16,20 0	784	196,0 00	14,20 0	-	-	878
UX90	123	294	28,9 00	72,00 0	17,70 0	1,13 0	195,0 00	22,60 0	-	-	1,06 0
UX300	123	307	28,9 00	72,00 0	17,90 0	1,18 0	195,0 00	23,00 0	-	-	1,05 0
UY16	121	726	7,19 0	111,0 00	6,330	254	191,0 00	8,690	-	-	238
UY100	121	581	9,55 0	105,0 00	8,130	340	190,0 00	11,10 0	-	-	315
UY300	122	354	14,5 00	97,80 0	12,60 0	500	189,0 00	22,20 0	-	-	650
UY600	122	316	15,3 00	96,40 0	13,10 0	511	188,0 00	24,80 0	-	-	712
UZ12	121	557	8,89 0	101,0 00	9,190	484	191,0 00	9,890	-	-	303
UZ100	122	413	15,1 00	95,70 0	12,40 0	536	191,0 00	16,30 0	-	-	557
UZ450	122	354	17,1 00	92,90 0	13,40 0	599	192,0 00	19,30 0	-	-	608
UZ800	122	342	17,0	91,10	13,30	598	190,0	19,50	-	-	665

			00	0	0		00	0			
U112	122	425	16,6 00	92,00 0	15,80 0	701	196,0 00	17,00 0	-	-	578
U1400	123	264	21,3 00	86,50 0	19,20 0	895	197,0 00	29,50 0	-	-	987
U1800	123	247	21,6 00	83,70 0	19,50 0	930	193,0 00	31,70 0	-	-	1,04 0
U213	121	433	14,5 00	92,90 0	14,30 0	640	195,0 00	15,90 0	-	-	480
U2100	122	331	17,3 00	92,00 0	16,60 0	750	196,0 00	23,00 0	-	-	618
U2200	122	307	17,7 00	88,30 0	17,40 0	791	193,0 00	25,20 0	-	-	700
U2300	122	284	18,7 00	86,50 0	17,90 0	826	190,0 00	27,40 0	-	-	766
U2400	123	234	20,4 00	85,60 0	18,60 0	909	187,0 00	33,10 0	-	-	976
U2500	123	223	20,5 00	85,60 0	18,60 0	916	189,0 00	34,10 0	-	-	1,01 0
U2600	123	223	20,7 00	85,60 0	18,40 0	895	187,0 00	34,10 0	-	-	1,02 0
YA17	121	577	9,53 0	102,0 00	12,20 0	435	192,0 00	10,10 0	-	-	360
YA100	121	449	12,2 00	95,90 0	13,60 0	557	191,0 00	13,70 0	-	-	483
YB11	120	758	4,37 0	111,0 00	4,690 0	144	190,0 00	5,830 0	-	-	155
YB100	121	581	8,65 0	103,0 00	8,910 0	338	190,0 00	10,20 0	-	-	299
YB500	121	364	11,1 00	93,20 0	12,90 0	534	189,0 00	19,80 0	-	-	488
YC12	120	662	3,84 0	112,0 00	3,860 0	120	191,0 00	5,070 0	-	-	103
YC100	120	636	6,66 0	107,0 00	6,450 0	229	189,0 00	8,540 0	-	-	219
YD9	120	758	6,03 0	107,0 00	6,450 0	229	191,0 00	7,470 0	-	-	216
YD100	121	421	12,2 00	94,80 0	12,50 0	496	192,0 00	14,40 0	-	-	427
YD450	120	341	15,5 00	90,20 0	14,50 0	621	191,0 00	20,20 0	-	-	615
YD800	122	329	16,5 00	90,20 0	15,40 0	670	192,0 00	22,70 0	-	-	692
YE8	121	662	5,30 0	110,0 00	5,750 0	193	192,0 00	6,300 0	-	-	204
YE100	121	400	12,4 00	95,90 0	12,60 0	509	192,0 00	15,20 0	-	-	438
YE450	125	274	17,2 00	91,50 0	16,10 0	673	195,0 00	28,10 0	-	-	790
YE800	123	269	16,9 00	89,50 0	15,80 0	661	191,0 00	27,40 0	-	-	791
YF23	120	1,03 0	2,96 0	113,0 00	3,090 0	72	192,0 00	4,690 0	-	-	88
YF200	120	854	4,50 0	109,0 00	4,650 0	144	190,0 00	6,240 0	-	-	143

YG15	121	473	11,0 00	100,0 00	10,60 0	521	191,0 00	12,00 0	-	-	301
YG100	120	806	4,52 0	112,0 00	5,160	228	191,0 00	6,020	-	-	164
YH1	126	100	51,0 00	37,30 0	26,80 0	2,46 0	207,0 00	44,40 0	-	-	2,03 0
YH100	125	137	53,2 00	34,00 0	19,90 0	2,59 0	212,0 00	29,20 0	-	-	1,95 0
YH250	125	87	53,9 00	32,40 0	19,90 0	2,59 0	213,0 00	29,50 0	-	-	2,04 0
YI8	121	517	8,41 0	105,0 00	8,800	362	192,0 00	9,030	-	-	273
YI100	121	533	9,33 0	101,0 00	9,310	399	192,0 00	9,590	-	-	305
YI450	121	509	9,84 0	100,0 00	9,930	411	191,0 00	10,10 0	-	-	321
YI800	121	437	11,0 00	95,40 0	11,00 0	484	191,0 00	11,50 0	-	-	351
YJ17	120	698	6,66 0	110,0 00	8,640	301	193,0 00	8,110	-	-	271
YJ100	121	461	11,8 00	94,10 0	12,70 0	545	194,0 00	12,80 0	-	-	428
YJ400	122	257	16,9 00	88,80 0	16,10 0	743	189,0 00	27,20 0	-	-	620
YK1	120	710	7,78 0	105,0 00	5,210	325	191,0 00	10,40 0	-	-	277
YK100	121	529	9,87 0	101,0 00	10,20 0	410	192,0 00	11,70 0	-	-	320
YK400	122	304	15,1 00	93,60 0	13,90 0	584	190,0 00	24,00 0	-	-	522
YK700	122	281	13,4 00	97,50 0	15,30 0	634	189,0 00	27,00 0	-	-	576
YL22	120	494	4,37 0	112,0 00	4,930	156	192,0 00	6,250	-	-	141
YL100	121	455	9,38 0	102,0 00	9,580	375	193,0 00	12,80 0	-	-	324
YL400	121	421	10,4 00	100,0 00	10,50 0	423	191,0 00	14,80 0	-	-	360
RA130	101	429	197	1,550	80	10	3,380	600	-	-	21
RB180	102	1,20 0	566	6,650	300	27	12,50 0	2,400	-	-	31
RC120	105	846	3,40 0	19,60 0	1,800	14	40,10 0	5,700	-	-	116
RD160	109	1,95 0	4,67 0	39,80 0	3,200	217	79,50 0	5,120	-	-	250
RE100	114	2,67 0	8,65 0	61,60 0	6,140	575	129,0 00	3,600	-	-	481
RF90	115	1,66 0	9,43 0	65,10 0	7,310	631	135,0 00	5,700	-	-	837
RG30	116	1,25 0	11,4 00	69,20 0	7,900	674	147,0 00	7,650	-	-	546
RH10	121	565	10,2 00	97,50 0	10,50 0	538	190,0 00	11,10 0	-	-	368
RI15	120	457	13,5 00	81,90 0	12,40 0	736	171,0 00	15,60 0	-	-	507

RJ10	122	390	11,4 00	95,70 0	11,00 0	633	190,0 00	12,80 0	-	-	626
RK90	115	1,93 0	10,5 00	62,60 0	7,820	701	137,0 00	5,100	-	-	1,02 0
RL110	111	2,53 0	6,44 0	45,50 0	5,000	417	96,60 0	4,830	-	-	971
RM100	109	2,13 0	5,78 0	37,00 0	4,500	347	80,20 0	5,100	-	-	318
RN75	115	2,02 0	3,89 0	79,10 0	4,500	359	132,0 00	5,000	-	-	491
RO80	114	1,59 0	6,73 0	62,60 0	5,400	483	122,0 00	7,200	-	-	965
RP50	110	1,96 0	2,33 0	45,50 0	2,800	182	82,00 0	6,990	-	-	137
RQ70	113	1,32 0	5,27 0	62,60 0	4,500	272	110,0 00	9,700	-	-	507
RR60	116	1,24 0	4,13 0	88,10 0	4,500	239	115,0 00	7,250	-	-	419
RS15	127	52	69,0 00	12,50 0	17,60 0	4,23 0	231,0 00	31,40 0	-	-	3,70 0
RT15	127	60	68,8 00	14,00 0	17,60 0	4,03 0	229,0 00	29,50 0	-	-	3,52 0
RU1	124	238	27,2 00	66,20 0	26,40 0	1,60 0	198,0 00	30,90 0	-	-	1,42 0
RV20	122	413	13,4 00	101,0 0	11,70 0	563	189,0 00	13,90 0	-	-	507
RW10	122	338	15,1 00	97,50 0	15,70 0	763	191,0 00	19,80 0	-	-	623
RX10	127	69	61,0 00	21,30 0	19,10 0	3,55 0	223,0 00	32,00 0	-	-	3,45 0
RY95	116	1,84 0	11,0 00	63,00 0	6,840	763	138,0 00	6,100	-	-	766
RZ1	128	102	75,3 00	10,70 0	15,10 0	4,72 0	253,0 00	26,50 0	-	-	4,33 0
CA0	124	315	10,9 00	105,0 00	9,230	237	185,0 00	28,10 0	-	-	720

COIPASA

sample	TiO ₂	Ca	Mg	Na	K	Li	Cl	SO ₄	CO ₃	HC O ₃	B
C0	368	253	12,1 20	100,4 00	9,080	338	186,0 00	25,30 0	-	785	2,20 8
CA150	124	194	14,1 00	104,0 00	10,00 0	275	172,0 00	54,00 0	-	-	870
CA250	126	164	10,5 00	111,0 00	8,330	212	132,0 00	104,0 00	-	-	644
CB0	123	301	10,7 00	108,0 00	9,190	237	187,0 00	29,30 0	-	-	690
CB150	126	102	23,0 00	94,70 0	14,30 0	416	168,0 00	80,10 0	-	-	1,35 0
C10	121	541	10,2 00	104,0 00	7,120	198	189,0 00	14,70 0	-	-	601
C20	122	521	15,1 00	99,10 0	11,60 0	333	188,0 00	17,60 0	-	-	952
C3	122	319	10,1	109,0	7,310	205	179,0	25,90	-	-	614

			00	00			00	0			
C40	122	509	10,8 00	107,0 00	8,560	230	187,0 00	18,00 0	-	-	640
C50	121	738	6,80 0	111,0 00	5,980	154	186,0 00	13,90 0	-	-	428
EMPEXA											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
EMP	239	259	8,48 0	67,20 0	3,400	213	120,0 00	34,10 0	-	430	702
PASTOS GRANDES (ALTIPLANO)											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
PGB	321	3,10 0	3,48 0	101,0 00	14,20 0	1,64 0	124,0 00	2,460	-	-	304 1
EL TARA											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
TAR-RT-001	1	108	12	340	7	4	596	46	19	83	18
TAR-RT-002	1	96	10	350	7	4	612	47	0	135	19
TAR-RT-003	1	88	8	275	6	3	478	35	6	91	15
TAR-RT-004	2	92	14	525	18	6	846	68	0	157	17
TAR-RT-005	1	80	20	440	8	4	688	66	0	141	11
TAR-RT-006	1	80	20	415	12	4	680	64	0	137	11
TAR-RT-007	90	300	135	56,00 0	580	420	87,40 0	6,060	0	2,35 0	710
TAR-RT-008	79	275	230	48,00 0	420	340	69,80 0	7,480	0	1,98 1	570
TAR-RT-009	16	100	208	7,100	480	34	10,74 0	1,036	52	1,68 9	119
TAR-RT-010	2	84	32	600	40	6	836	159	62	333	16
TAR-RT-011	112	1,45 0	430	80,00 0	700	440	127,0 00	11,24 0	0	1,10 2	486
TAR-RT-012	100	1,40 0	440	76,00 0	640	420	123,2 00	10,70 0	0	1,06 0	415
AGUAS CALIENTES NORTE											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
ACN-RT-001	1	94	24	340	8	4	602	58	0	154	8
ACN-RT-002	1	94	26	225	7	3	480	55	0	160	6
ACN-RT-003	1	86	22	330	12	4	578	62	8	98	5
ACN-RT-004	3	240	12	1,100	18	6	2,100	101	0	50	9
ACN-RT-005	12	800	50	4,300	56	20	8,260	270	0	209	28
ACN-RT-006	5	320	100	1,600	34	10	2,930	229	0	452	16
ACN-RT-007	50	2,80 0	820	23,00 0	1,020	130	40,80 0	3,010	0	842	392
PUJSA											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B

PUJ-RT-001	-	125	35	280	28	2	338	384	0	173	0
PUJ-RT-002	-	180	790	26,00 0	2,825	175	37,00 0	15,00 0	834	1,32 4	450
PUJ-RT-003	-	180	835	32,00 0	3,175	200	39,80 0	22,60 0	1,01 6	1,47 7	529
PUJ-RT-004	-	70	28	260	26	1	286	264	0	225	0
PUJ-RT-005	-	50	12	220	16	1	232	208	0	128	0
PUJ-RT-006	-	175	250	23,00 0	975	60	12,88 0	32,20 0	586	0	177
PUJ-RT-007	-	300	98	9,500	300	20	3,520	15,44 0	457	0	184
PUJ-RT-008	-	80	16	1,050	32	2	441	1,600	52	186	0
PUJ-RT-009	-	1,00 0	1,51 5	52,00 0	3,400	400	87,20 0	14,34 0	0	1,54 2	317
PUJ-RT-010	-	525	183	13,00 0	525	27	5,000	21,96 0	548	568	230

LOYOQUES

sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
LOY-RT-001	3	220	34	890	22	6	1,765	97	40	0	4
LOY-RT-002	123	18,0 00	2,30 0	9,600	123	350	202,0 00	1,820	0	655	430
LOY-RT-003	123	15,8 50	2,47 5	100,0 00	123	375	196,8 00	1,720	0	779	681
LOY-RT-004	122	17,6 00	2,85 5	55,00 0	128	425	194,8 00	1,840	0	827	756
LOY-RT-005	102	5600	2,13 5	62,00 0	1,650	275	114,2 00	2,600	0	733	527

AGUAS CALIENTES
CENTRO

sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
ACC-RT-001	15	2,42 5	415	3,750	325	10	10,74 0	1,302	0	143	0
ACC-RT-002	7	600	413	2,150	228	5	4,660	752	0	448	0
ACC-RT-003	11	1,65 0	273	2,600	240	8	7,260	882	0	142	0
ACC-RT-004	44	875	3,33 8	19,00 0	1,025	45	33,80 0	5,530	0	819	33
ACC-RT-005	9	575	293	2,800	150	8	5,840	236	0	144	0

EL LACO

sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
LACO	210	820	6,25 1	62,20 0	4,800	101	109,6 30	15,36 0	-	620	1,07 8
LAC-RT-001	44	1,30 0	2,03 5	19,00 0	1,525	40	34,20 0	5,370	0	400	0
LAC-RT-002	47	1,22 5	2,64 5	21,00 0	1,850	33	36,30 0	7,280	0	428	0
LAC-RT-003	43	800	2,16 5	19,00 0	1,550	28	32,20 0	5,930	0	370	0
LAC-RT-004	26	775	1,10	12,00	900	20	18,08	3,768	0	367	0

			2	0			0				
LAC-RT-005	2	190	34	650	95	2	1,090	340	0	175	0
AGUAS CALIENTES SUR											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
ACT-RT-001	33	1,625	1,370	13,000	900	18	24,360	4,160	0	225	0
ACT-RT-002	6	275	170	2,100	182	3	3,590	642	0	81	0
ACT-RT-003	2	180	62	500	60	1	980	447	0	109	0
ACT-RT-004	2	170	60	550	60	1	935	424	0	104	0
ACT-RT-005	7	425	193	2,400	155	3	4,170	606	0	353	0
ACT-RT-006	1	410	33	250	27	1	256	1,186	0	57	0
ACT-RT-007	4	230	150	1,100	85	5	1,850	689	0	243	0
ACT-RT-008	2	140	85	650	46	3	1,135	343	0	164	0
AGUAS CALIENTES SUR SUR											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
ACS-RT-001	1	85	43	400	40	1	590	332	0	92	1
ACS-RT-002	1	85	43	375	30	1	594	334	0	93	1
ACS-RT-003	1	85	43	400	40	2	590	330	0	96	2
ACS-RT-004	25	750	850	10,300	1,050	35	18,400	4,060	66	349	131
ACS-RT-005	1	100	16	175	4	<1	194	334	0	42	0
ACS-RT-006	1	100	16	175	3	<1	193	344	0	42	0
ACS-RT-007	1	83	16	175	3	<1	197	342	0	41	0
ACS-RT-008	3	190	100	875	100	3	1,380	1,010	0	111	9
ACS-RT-009	3	170	80	750	80	2	1,115	895	0	99	7
ACS-RT-010	7	375	98	3,050	270	9	3,930	2,160	0	117	40
PAJONALES											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
PAJ-RT-001	16	775	500	6,500	325	6	11,580	1,084	0	76	36
PAJ-RT-002	15	775	475	5,800	305	6	10,740	894	0	74	31
PAJ-RT-003	1	625	250	5,000	285	5	8,940	1,042	0	75	27
PAJ-RT-004	36	2,125	1,175	1,360	925	16	28,450	2,850	0	190	85
PAJ-RT-005	35	1,900	1,150	15,000	900	16	27,500	2,685	0	182	91
PAJ-RT-006	39	2,375	1,275	13,800	1,025	18	29,300	3,100	0	208	102
PAJ-RT-007	67	2,525	1,975	33,400	1,725	58	62,000	2,550	0	314	177
PAJ-RT-008	71	2,625	2,175	33,800	1,825	62	67,400	2,820	0	448	190
PAJ-RT-009	48	1,300	1,525	2,050	1,275	40	40,400	1,650	0	334	125
PAJ-RT-010	78	5,700	2,300	33,800	1,675	31	76,800	590	0	193	86

PAJ-RT-011	54	4,94 5	2,27 5	20,10 0	1,208	18	47,60 0	780	0	134	54
PAJ-RT-012	47	4,63 5	2,02 5	16,60 0	1,135	18	39,30 0	0	0	135	46
PAJ-RT-013	68	5,01 8	1,75 0	30,80 0	1,803	35	61,30 0	3,700	0	511	329
PAJ-RT-014	69	5,01 8	1,80 0	32,00 0	1,828	35	62,20 0	3,730	0	523	349
PAJ-RT-015	69	5,01 8	1,77 5	31,70 0	1,810	35	63,40 0	3,720	0	516	334
PAJ-RT-016	96	5,01 8	3,05 0	52,80 0	2,800	45	104,0 00	200	0	864	524
PAJ-RT-017	96	5,01 5	3,27 5	53,40 0	2,825	44	102,4 00	2,820	0	854	457
PAJ-RT-018	84	5,01 8	2,40 0	4,120	2,315	41	82,40 0	3,380	0	704	402
PAJ-RT-019	19	1,54 0	375	6,100	353	8	13,90 0	725	0	46	54
PAJ-RT-020	19	1,54 2	375	6,300	345	8	13,35 0	705	0	46	54
PAJ-RT-021	23	2,06 5	475	7,500	405	9	17,10 0	865	0	52	58
PAJ-RT-022	23	1,91 5	450	7,600	410	9	16,40 0	1,055	0	60	59
PAJ-RT-023	24	1,98 0	500	7,800	430	10	17,45 0	1,155	0	64	64
PAJ-RT-024	23	1,90 0	475	7,800	405	10	17,00 0	1,085	0	63	62
PAJ-RT-025	103	9,50 0	5200	50,80 0	2,200	36	118,8 00	2,060	0	399	195

GORBEA

sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
GOR-RT-001	66	163	39,5 00	66,00 0	5,000	475	162,8 06	107,3 67	0	0	2,08 4
GOR-RT-002	66	165	38,5 00	64,00 0	4,600	500	156,5 95	102,3 55	0	0	1,98 6
GOR-RT-003	76	410	27,5 00	52,00 0	5,000	300	124,7 11	74,82 5	0	0	1,50 9
GOR-RT-004	76	275	28,0 00	52,00 0	5,000	300	123,7 53	74,29 0	0	0	1,45 8
GOR-RT-005	5	425	550	1,300	25	5	2,486	3,107	0	0	4,55 9

AGUA AMARGA

sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
AAM-RT-001	15	2363	325	3,600	185	14	10,54 0	1,308	0	112	69
AAM-RT-002	15	2448	300	3,700	198	14	10,65 0	1,150	0	113	69
AAM-RT-003	109	23,0 00	3,52 5	51,20 0	1,980	58	136,0 00	1,120	0	166	397
AAM-RT-004	113	25,0 00	4,22 5	59,40 0	2,035	61	150,0 00	1,200	0	162	426

AAM-RT-005	105	23,0 00	3,00 0	47,60 0	1,683	56	124,4 00	1,120	0	170	392
AMA-04	93	24,1 00	3,09 0	43,20 0	2,490	157	121,0 00	674	0	0	515
LA ISLA											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
LIS-RT-001	5	150	78	2,000	42	13	3,167	666	0	32	0
LIS-RT-002	30	350	450	13,00 0	880	98	22,66 1	2,118	0	73	10
LIS-RT-003	8	165	125	3,000	75	23	4,839	857	0	41	0
LIS-RT-004	13	475	183	5,200	275	30	8,650	1,201	0	35	0
LIS-RT-005	15	375	250	6,200	375	35	9,928	1,273	0	42	0
LIS-RT-006	23	425	25	9,600	750	73	16,20 0	1,624	0	50	0
LIS-RT-007	123	525	5,30 0	12,00 0	8,600	850	179,3 88	14,29 2	0	188	272
LIS-RT-008	123	500	5,00 0	130,0 00	800	300	196,7 01	13,68 7	0	152	268
LIS-RT-009	123	475	4,90 0	126,0 00	800	800	180,0 54	13,36 2	0	152	262
LIS-RT-010	122	525	5,40 0	122,0 00	8,500	875	191,3 38	14,86 4	0	190	297
LIS-RT-011	120	525	8,30 0	110,0 00	108,0 00	1,15 0	189,0 57	17,88 4	0	1,17 3	284
LIS-RT-012	45	195	925	21,00 0	1,575	78	35,35 1	2,346	44	132	26
AGUILAR											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
AGU-RT-001	113	55,0 00	6,80 0	60,00 0	2,600	375	212,1 26	1,382	0	860	692
AGU-RT-002	113	55,0 00	6,90 0	60,00 0	2,600	375	206,7 50	0	0	862	697
AGU-RT-003	115	45,0 00	6,10 0	62,00 0	2,600	350	191,1 25	0	0	1,02 9	829
LAS PARINAS											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
LPA-RT-001	9	105	95	4,100	54	10	6,058	498	0	211	14
LPA-RT-002	7	100	65	2,600	41	7	4,431	341	0	209	6
LPA-RT-003	7	113	75	3,300	44	8	4,786	368	0	217	0
LPA-RT-004	7	130	73	2,900	45	7	4,672	480	0	87	0
LPA-RT-005	122	725	3,20 0	100,0 00	500	350	170,1 11	12,79 6	0	580	423
LPA-RT-006	123	625	3,60 0	105,0 00	6,000	400	167,5 84	12,52 2	0	651	447
SURIRE											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
SUR0	236	890	3,83 0	73,20 0	13,20 0	540	131,3 80	11,43 0	-	-	3,70 0

SUR-22	12	1,160	84	1,710	310	8	1,800	4,060	26	297	544
SUR-23	285	850	2,960	93,400	14,100	530	155,000	11,500	0	0	1,300
PEDERNALES											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O ₃	B
PED-26	1	135	43	711	50	3	1,250	305	1	127	9
PED-27	1	125	42	711	48	3	1,180	341	8	126	9
PED-28	2	166	58	817	61	3	1,450	387	1	92	10
PED-29	1	145	46	699	51	3	1,260	334	0	103	10
MARICUNGA											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O ₃	B
MAR-16	4	165	58	1,220	161	11	2,200	169	0	273	18
MAR-17	2	147	17	543	63	5	927	175	0	227	11
MAR-19	51	1,240	680	16,200	1,230	92	30,800	171	0	0	50
PINTADOS											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O ₃	B
PIN-07	68	4,530	0	19,300	2,010	69	39,800	1,900	0	0	21
PIN-16	1	43	9	135	49	1	689	121	1	9	10
PIN-41	23	529	175	7,080	696	15	5,890	58	11	124	60
HUASCO											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O ₃	B
HCO0	277	610	5,080	65,000	13,500	480	112,980	26,700	-	-	2,333
HCO-6	0	11	8	122	13	<1	82	74	1	2	2
HCO-9	0	13	5	45	11	<1	20	156	0	59	1
COPOSA											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O ₃	B
COP-03	0	7	4	14	3	<1	10	38	0	9	1
COP-07	3	214	163	573	45	2	1,010	488	2	79	4
COP-08	0	32	18	29	6	<1	28	67	0	146	1
COP-09	3	362	53	483	50	1	753	1,030	1	111	3
COP-11	112	742	4,930	31,100	3,080	90	50,800	20,400	16	465	101
COP-16	2	119	44	382	18	1	742	235	1	63	2
MICHINCHA											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O ₃	B
MIC-08	0	25	19	35	18	<1	18	-	0	90	<1
MIC-09	0	32	8	41	16	<1	25	-	2	46	<1
MIC-10	1	69	25	33	12	<1	24	-	0	25	<1
MIC-11	0	10	3	15	7	<1	10	-	0	31	<1

MIC-13	0	20	12	15	6	<1	14	-	0	37	<1
ALCONCHA											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO 3	HC O3	B
ALC-01	1	150	2	97	13	<1	90	-	0	87	3
CARCOTE											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO 3	HC O3	B
CAR-04	176	12,000	1,990	49,500	2,880	136	107,000	1,280	6	134	426
CAR-09	2	88	32	593	53	2	1,130	35	0	66	5
CAR-16	322	2,810	6,850	101,000	12,500	339	19,500	2,440	0	0	0
CAR-19	20	678	352	5,680	712	4	14,690	2,320	5	136	66
ASCOTAN											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO 3	HC O3	B
ASCO	154	920	5,125	45,000	3,530	186	70,000	25,000	-	2,900	2,520
ASC-01	3	111	22	679	100	8	1,160	179	0	225	40
ASC-02	1	58	29	192	26	1	315	105	1	211	3
ASC-03	0	85	21	524	76	6	898	120	0	204	30
ASC-04	2	131	31	570	65	5	1,080	191	1	67	7
ASC-15	2	87	22	636	77	6	888	124	0	200	30
ASC-16	0	19	4	96	15	1	107	63	0	90	4
ASC-17	5	205	143	1,110	113	5	1,680	672	3	714	58
ASC-41	118	1,170	2,410	35,400	4,890	245	58,600	12,200	40	958	1,030
ASC-47	3	15	57	860	96	4	1,080	194	80	365	21
ATACAMA											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO 3	HC O3	B
ATA0	370	520	6,130	103,000	12,900	760	193,100	16,140	-	560	1,705
ATAdo	335	300	8,500	98,000	19,500	1,200	182,800	25,500	-	220	1,673
ATA	370	450	9,650	91,100	23,600	1,570	189,500	15,900	-	230	440
Do1	310	1,100	6,350	85,800	13,000	940	163,900	8,540	0	280	360
Do2	190	900	5,330	45,100	9,000	520	83,780	18,170	0	240	360
Do3	73	360	1,810	18,220	4,220	290	36,750	3,430	0	320	100
Do4	62	1,080	1,930	14,840	2,900	190	27,500	7,900	0	100	88
Do5	40	1,060	750	10,280	1,690	130	20,300	2,160	0	92	61
ATA-05	2	136	60	520	50	4	959	271	1	254	20
ATA-22	4	151	128	1,070	196	13	1,880	552	1	429	13
IMILAC											

sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
IMI-01	1	39	3	132	11	<1	96	233	1	28	2
IMI-03	6	593	52	1,460	73	73	1,970	1,900	0	68	6
IMI-04	2	11	7	30,40 0	19	1	1,000	60	13	73	2
IMI-8D	12	642	66	3,800	94	2	6,430	1,010	0	66	8
PUNTA NEGRA											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
PUN-08	7	78	24	2,420	140	3	3,980	101	1	70	2
PUN-16	3	9	53	653	89	3	1,560	420	0	40	20
PUN-18	3	158	24	791	104	2	1,440	240	0	6	10
PUN-19	1	19	3	127	15	<1	172	30	5	79	1
PUN-20	1	3	0	175	8	<1	132	37	30	129	0
PUN-24	0	31	2	139	9	<1	244	37	1	13	0
IGNORADOS											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
IGN-04	10	485	445	342	342	1	444	6,490	0	0	18
IGN-05	13	505	707	637	637	2	1,410	7,300	0	0	29
LA AZUFRERA											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
AZU0	400	88	48,6 0	60,00 0	14,96 0	86	172,1 30	87,99 0	-	0	740
AZU-07	1	117	9	34	11	<1	157	148	0	29	0
JAMA											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
JA1	7	178 0	402	2,004	201	6	2,560	7,009	0	349	539
JA2	7	991	243	2,860	343	11	2,627	4,587	0	387	3,07 0
JA3	6	131	17	3,523	210	10	6,170	2,051	0	332	236
JA4	6	122	48	3,422	344	2	4,927	2,537	0	234	493
JA5	6	65	47	4,183	297	2	5,868	1,219	0	263	239
JA6	91	647	469	60,43 2	4,591	262	97,01 7	14,61 5	0	286	1,42 1
JA7	6	122	48	3,475	344	2	4,929	2,535	0	341	493
JA8	6	122	47	3,482	344	2	4,930	2,541	0	344	494
JA9	90	647	467	60,42 7	3,356	262	97,01 8	14,61 6	0	282	1,42 1
JA10	92	646	492	60,43 7	4,658	261	97,01 7	14,61 6	0	272	1,42 2
OLAROS											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
OL1	157	584	1,53 9	112,1 91	5,051	771	181,7 49	9,678	0	421	2,09 0

OL2	158	529	1,98 1	112,1 90	5,504	968	181,0 03	10,22 2	0	419	2,09 0
OL3	155	526	1,97 2	107,6 54	6,019	1,00 7	179,6 27	10,19 2	0	435	2,30 2
OL4	157	481	2,30 1	107,9 56	7,984	1,20 7	180,8 37	8,982	0	328	3,17 6
OL5	137	448	2,18 3	69,85 5	6,563	1,09 2	175,6 95	10,58 5	0	343	2,51 1
OL6	153	496	2,27 6	79,67 0	7,870	1,21 3	187,0 41	10,01 5	0	366	2,25 1
OL7	158	513	1,98 8	107,7 59	5,179	868	176,3 45	9,856	0	331	2,42 2
OL8	160	537	2,18 6	107,0 69	5,501	1,09 3	184,9 87	10,20 3	0	280	3,03 7
OL9	159	447	1,62 8	112,3 32	6,003	1,06 1	179,0 91	10,65 8	0	247	2,80 0
OL10	145	598	1,97 0	71,78 3	6,569	861	171,6 05	10,37 4	0	266	2,65 5
CAUCHARI											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO 3	HC O3	B
CA1	97	556	1,85 1	69,82 6	2,576	535	108,0 14	9,060	0	279	1,33 7
CA2	92	764	1,50 9	58,03 2	2,714	442	102,2 11	14,47 1	0	355	2,19 0
CA3	124	603	1,67 0	83,70 9	8,594	1,74 0	130,4 06	11,95 8	0	490	2,83 4
CA4	139	477	1,59 4	101,3 47	4,769	713	149,8 18	16,35 6	0	461	2,30 4
CA5	144	599	2,10 7	104,5 15	4,733	873	163,8 86	9,685	0	623	2,12 6
SALINAS GRANDES											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO 3	HC O3	B
SG1	122	877	115	6,413	694	25	10,20 3	3,982	0	375	527
SG2	120	1,30 7	803	86,37 5	3,325	218	140,6 86	1,746	0	342	509
SG3	119	1,46 2	1,01 7	84,71 8	3,498	244	141,3 54	1,573	0	344	542
SG4	121	1,44 2	1,13 0	86,81 7	3,762	270	140,2 66	2,174	0	339	444
SG5	116	1,90 6	1,30 1	77,46 8	4,521	382	140,4 12	1,908	0	256	452
SG6	116	1,47 2	843	79,32 7	3,651	241	139,3 02	2,388	0	278	342
SG7	116	2,11 9	2,28 9	67,95 4	8,149	1,01 8	139,0 71	1,441	0	230	361
SG8	119	1,43 2	924	80,24 6	3,890	247	139,7 97	1,959	0	351	309
SG9	118	1,39 5	1,02 2	85,69 3	4,668	325	137,8 46	1,900	0	368	512
SG10	116	1,78 7	1,23 3	77,53 9	5,196	352	137,6 91	1,751	0	260	469

GUAYATAYOC											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
GG3	48	2,08 4	292	20,00 0	8070	45	58,50 0	7,560	0	384	310
GQ0	86	1,38 2	134	32,40 0	21,00 0	125	252,8 00	13,00 0	0	286	450
GG4	81	1,27 0	123	31,70 0	20,87 0	117	245,0 90	13,50 0	0	276	321
CENTENARIO											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
CE0	343	320	7,55 0	112,3 00	8,170	1,02 0	192,7 00	19,98 0	-	-	3,76 5
CE1	26	831	916	6,752	966	65	14,59 5	2,960	0	498	365
CE2	26	508	604	7,134	843	23	14,27 6	3,056	0	496	277
CE3	41	395	1,19 6	10,61 3	2,860	106	17,13 3	12,46 1	0	322	434
CE4	45	842	1,21 7	11,76 7	2,914	133	18,46 6	12,66 3	0	343	581
CE5	49	619	2,27 7	10,45 0	3,025	377	21,49 3	12,18 4	0	494	402
DIABLILLOS											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
DI1	38	791	1,82 4	9,533	746	47	21,89 7	3,541	0	230	360
DI2	26	794	1,12 1	6,943	687	81	15,04 1	2,715	0	376	584
DI3	78	1,40 2	933	21,53 5	7,876	235	38,27 0	9,587	0	351	808
DI4	81	1,48 6	964	21,78 4	6,370	357	37,73 1	11,61 8	0	334	614
HOMBRE MUERTO											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O3	B
MH0	341	1,00 0	268	121,9 00	9,340	914	194,8 00	11,10 0	-	-	1,45 5
HM1	31	792	916	8,197	2,984	114	18,76 6	1,017	0	133	377
HM2	33	410	678	8,871	4,310	85	19,49 0	1,216	0	204	538
HM3	194	1,16 2	1,11 4	64,92 7	6,430	966	137,9 10	1,284	0	62	1,32 3
HM4	205	592	833	72,48 4	4,022	674	139,4 09	1,312	0	321	515
HM5	196	874	1,91 5	62,40 0	5,660	1,01 3	125,3 13	934	0	105	149 0
INCAHUASI											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO	HC	B

										3	O3
IN1	48	1,28 4	5283	7,360	2,754	22	32,63 1	362	0	315	114
IN2	69	976	10,3 76	6,548	6,896	82	48,67 5	930	0	75	558
IN3	100	1,19 4	15,8 94	12,34 4	4,012	132	72,91 3	678	0	15	510
IN4	107	988	14,6 87	11,78 2	7,130	145	74,35 3	736	0	44	570
IN5	86	1,07 4	9828	10,49 1	7,732	96	61,34 5	855	0	276	427
PASTOS GRANDES (PUNA)											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO 3	HC O3	B
PG0	333	740	2,98 0	118,2 00	4,730	440	178,7 00	26,08 0	-	-	2,22 0
PG1	154	766	3,78 5	50,22 0	919	355	97,05 3	968	0	822	702
PG2	227	745	2,43 1	80,73 2	652	510	161,3 90	970	0	896	784
PG3	157	512	4,47 9	50,67 3	5,506	410	102,8 50	970	0	980	300
PG4	158	580	5,64 6	49,77 2	3,590	305	101,0 60	943	0	955	455
PG5	158	498	5,61 1	41,46 4	5,914	857	91,50 5	14,90 3	0	865	812
POZUELOS											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO 3	HC O3	B
PZ1	237	447	1,15 3	89,66 1	1,011	96	154,5 21	8,864	0	213	650
PZ2	291	558	1,85 4	107,7 72	2,976	207	176,2 83	9,060	0	278	1,36 6
PZ3	290	2,03 2	2,58 7	102,7 15	6,314	712	178,2 50	10,78 5	0	12	398
PZ4	292	604	1,81 6	115,9 75	4,044	260	198,9 70	2,974	0	0	1,65 5
PZ5	254	1,60 5	1,71 5	87,01 2	5,213	940	150,6 70	13,11 5	0	0	2,10 2
PZ6	295	1,61 0	2,09 9	102,1 52	4,728	835	190,9 56	9,685	0	0	202
PZ7	256	444	1,18 0	91,67 4	1,024	86	171,3 60	8,812	0	240	415
PZ8	205	672	741	76,59 1	816	75	122,0 34	9,005	0	266	396
RATONES											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO 3	HC O3	B
RA1	28	1,21 3	135	9,780	852	88	17,26 0	2,731	0	647	312
RA2	83	1,54 0	323	30,53 3	3,205	260	54,45 7	5,125	0	415	433
RA3	72	1408	210	27,31	3,024	125	53,19	3,580	0	348	509

2

2

ANTOFALLA											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O ₃	B
AN1	55	2,964	705	15,975	2,490	164	29,058	8,714	0	77	530
AN2	185	662	725	63,713	3,518	615	113,985	7,725	0	358	815
AN3	148	535	816	55,770	807	311	88,201	7,815	0	241	878
AN4	25	1,310	365	6,889	365	95	14,100	1,830	0	710	814
AN5	19	692	644	5,271	476	46	9,460	1,005	0	865	807
AN6	9	286	206	2,580	166	25	4,873	356	0	492	415
ARIZARO											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O ₃	B
AR0	321	760	1,840	119,500	160	100	190,700	9,260	-	-	138
AR1	274	415	484	100,581	4,112	106	182,213	12,483	0	81	1,109
AR2	155	473	545	53,107	2,061	83	98,090	5,521	0	122	2,066
AR3	92	512	1,616	23,456	5,686	375	42,611	17,620	0	74	1,216
AR4	130	517	7,755	25,565	7,543	318	58,847	30,246	0	119	3,306
AR5	308	429	4,114	99,478	10,071	180	184,234	30,390	0	225	3,225
AR6	80	515	515	24,944	1,098	112	39,243	13,923	0	96	1,232
AR7	105	494	4,092	24,990	10,011	465	56,897	17,620	0	60	1,313
AR8	48	515	1,070	15,564	1,480	52	23,468	7,922	0	93	2,366
AR9	52	432	376	10,805	1,315	97	16,662	2,497	0	75	3,382
AR10	64	410	484	22,530	1,180	122	38,534	7,682	0	74	380
POCITOS											
sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO ₃	HC O ₃	B
PC0	327	600	1,290	123,100	3,400	97	190,600	7,440	-	-	708
PC1	32	1,235	246	9,584	421	27	18,020	2,690	0	74	70
PC2	34	1,443	285	9,667	105	30	17,859	6,240	0	56	85
PC3	278	795	1,225	102,597	610	101	182,235	9,050	0	0	208
PC4	299	815	1,384	110,862	1,197	86	190,750	4,300	0	0	194
PC5	38	1,54	260	11,44	1,488	46	18,34	6,955	0	37	88

			0	0			5				
PC6	41	412	568	12,54 4	1,670	65	23,95 0	5,272	0	37	170
PC7	36	645	633	10,38 0	1,771	68	16,05 5	7,925	0	0	162
PC8	29	408	596	10,30 1	1,612	53	15,25 2	3,897	0	15	60
PC9	30	944	578	10,29 8	1,644	22	18,09 5	2,102	0	22	63
PC10	45	365	135	12,86 3	1,702	68	20,33 3	9,970	0	13	63

RINCON

sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO 3	HC O3	B
RI0	339	280	2,12 0	122,2 00	6,570	350	190,5 00	15,99 0	-	-	1,60 9
RI1	281	1,05 0	1,81 5	95,23 5	7,130	244	176,9 36	17,48 4	0	150	1,90 4
RI2	285	813	2,29 7	99,19 9	6,543	270	172,5 57	25,23 3	0	134	2,09 8
RI3	152	805	2,21 0	47,03 0	5,017	112	84,82 3	13,31 4	0	163	1,61 2
RI4	145	833	2,28 4	47,76 4	4,841	122	83,63 5	14,58 4	0	177	1,40 5
RI5	140	1,10 2	1,78 8	41,14 0	6,974	360	73,81 4	15,41 5	0	210	1,81 2
RI6	141	910	2,04 4	58,94 5	6,530	268	74,72 2	16,11 2	0	147	2,04 1
RI7	152	930	1,85 2	50,16 3	6,812	195	96,23 1	10,34 1	0	207	1,90 4
RI8	183	652	2,03 0	61,24 0	7,315	651	108,3 78	11,01 2	0	215	1,41 2
RI9	187	814	1,91 8	59,15 2	7,015	337	107,5 00	10,40 4	0	219	1,78 7
RI10	190	630	2,01 6	60,48 8	4,916	150	102,3 34	10,48 2	0	112	1,47 0

RIO GRANDE

sample	TDS	Ca	Mg	Na	K	Li	Cl	SO4	CO 3	HC O3	B
RG0	260	800	2,60 0	92,40 0	3,710	420	148,9 00	10,61 0	-	-	1,67 3
RG1	285	1,86 2	2,21 5	96,48 5	3,012	336	162,8 40	18,68 0	0	416	414
RG2	280	1,96 6	2,19 0	98,18 7	3,305	274	163,7 73	19,99 0	0	297	302
RG3	257	1,98 7	2,13 6	89,37 3	3,315	468	169,0 85	8,654	0	25	415
RG4	207	2,10 4	2,23 0	77,91 0	3,588	502	131,5 28	6,940	0	76	545
RG5	260	1,97 0	1,39 0	87,76 1	2,469	139	166,2 35	4,974	0	72	348
RG6	259	2,10 3	1,50 5	99,82 8	2,645	152	164,6 15	5,134	0	98	366

RG7	252	2,10 0	2,23 4	103,4 66	3,316	480	162,2 00	4,909	0	44	423
RG8	199	1,28 3	2,97 4	74,57 2	2,890	692	131,6 65	2,022	0	366	315
RG 9	234	2,33 0	2,21 2	78,28 8	3,325	475	150,7 55	3,080	0	381	442
RG10	226	2,04 9	2,08 4	75,34 2	3,191	443	147,7 65	2,315	0	337	404

- not reported

Table 3. Mean values for hydrochemical compositions of brines from Andean salt pans. Values correspond to averages computed on data presented in Table 2. n: number of samples. TDS in g L⁻¹, the remaining concentrations in mg L⁻¹.

N°	Salt pan	n	Mean										
			TDS	Ca	Mg	Na	K	Li	Cl	SO ₄	CO ₃	HCO ₃	B
1	Surire	3	178	96,7	2,23 1	56,10 3	9,20 3	359	96,06 0	8,99 7	13	99	1,84 8
2	Coipasa	11	145	350	12,2 11	104,8 36	9,15 5	258	178,0 91	37,3 55	-	785	883
3	Uyuni	16	125	550	15,5 33	87,67 0	12,3 89	715	183,8 85	17,1 49	-	4	646
4	Empexa	1	239	259	8,48 0	67,20 0	3,40 0	213	120,0 00	34,1 00	-	430	702
5	Huasco	3	93	221	1,96 4	21,72 2	4,50 8	160	37,69 4	8,97 7	<1	20	779
6	Coposa	6	20	246	869	5,430	534	16	8,890	3,71 0	3	146	19
7	Michincha	5	<1	31	13	28	12	<1	18	-	<1	46	<1
8	Alconcha	1	1	150	2	97	13	<1	90	-	0	87	3
9	Carcote	4	234	7,03 9	4,15 1	70,56 7	7,26 8	217	61,81 2	3,03 8	5	169	224
10	Ascotan	10	29	280	786	8,497	899	47	13,58 1	3,88 5	14	593	374

1	Pastos Grandes		32	3,10	3,48	101,0	14,2	1,64	194,0	2,46		3,04
1	(Altiplano)	1	1	0	0	00	00	0	00	0	-	-
1	Atacama	10	18	606	4,06	46,79	8,70	562	90,04	9,85	<1	273
2			1		4	3	6		7	6		482
1	El Tara	12	35	346	165	22,50	243	140	35,24	3,08	12	772
3						4			0	3		201
1	Aguas Calientes	7	10	633	151	4,414	165	25	7,964	541	1	281
4	Norte											66
1	Pujsa	10	-	269	376	15,73	1,13	89	18,67	12,4	34	562
5						1	0		0	00	9	189
1	Loyoques o	5	94	11,4	1,96	53,69	409	2,66	141,9	1,61	8	599
6	Quisquiro			54	0	8			13	5		480
1	Aguas Calientes	5	17	1,22	946	6,060	394	15	12,46	1,74	0	339
7	Centro			5					0	0		7
1	El Laco	6	62	852	2,37	22,30	1,73	37	38,58	6,34	0	393
8					2	8	7		3	1		180
1	Aguas Calientes Sur	8	7	432	265	2,569	189	4	4,660	1,06	0	167
9										2		0
2	Imilac	4	5	321	32	8,948	49	19	2,374	801	4	59
1												4
2	Punta Negra	6	2	50	18	718	61	1	1,255	144	6	56
2												5
2	Aguas Calientes Sur	10	4	202	131	1,668	163	5	2,718	1,01	7	108
3	Sur									4		19
2	Pajanoles	25	49	3,23	1,56	19,43	1,22	25	45,58	1,81	0	283
4				4	0	7	1		8	0		160
2	La Azufrera	2	28	441	34,4	42,31	10,7	61	121,1	65,8	0	36
5			7		00	7	73		57	34		532
2	Gorbea	5	58	288	26,8	47,06	3,92	316	114,0	72,3	0	0
6					10	0	5		70	89		2,31
2	Ignorados	2	11	495	576	490	490	2	927	6,89	0	0
7										5		24
2	Agua Amarga	6	75	16,6	2,41	34,78	1,42	60	92,09	1,09	0	121
8				52	1	3	9		8	5		311
2	Aguilar	3	11	51,6	6,60	60,66	2,60	367	203,3	461	0	917
9			3	67	0	7	0		34			739

3					2,57	46,66	10,8		87,27	7,01			
0	La Isla	12	62	390	8	7	98	402	8	5	4	188	118
3					1,18	36,31	1,11		59,60	4,50			
2	Las Parinas	6	46	300	5	7	4	130	7	1	0	326	148
3													
4	Pedernales	4	1	143	47	735	53	3	1,285	342	2	112	10
3									11,30				
8	Maricunga	3	19	517	252	5,988	485	36	9	172	0	167	26
3					1,10	11,2			57,98				
9	Incahuasi	5	82		3	14		95	3	712	0	145	436
4					1,07		25,03	1,30		43,28	4,57		
0	Antofalla-Botijuelas	6	73		5	577		205	0	4	0	457	710
4					2,16	88,51	3,1		154,4	7,93			
1	Río Grande	11	24		1	0	1	298	87	7	0	211	513
4													
2	Arizaro	11	14		2	0	6	188	2	06	0	102	1,79
4													4
3	Hombre Muerto	6	16		805	954	5,46	5,45	105,9	2,81	0	165	950
4							3	8	48	1			
4	Diablillos	4	56		1,11	1,22	14,94	3,92	28,23	6,86	0	323	592
4					9	6	9	0	5	5			
5	Ratones	3	61		1,38		22,54	2,36	41,63	3,81	0	470	418
4					7		2	0	6	2			
6	Centenario	6	68		2,29	26,50	3,13	288	46,44	10,5	0	431	971
4					3	3	0		4	51			
7	Pocitos-Quirón	11	10				38,51	1,42	64,68	5,98	0	25	170
4							2	0	1	6			
8	Pozuelos	8	26		1,07	1,64	96,69	3,26	167,8	9,03	0	126	898
4							1	4	80	8			
9	Pastos Grandes (Puna)	6	19		4,15	65,17	3,55	476	122,0	7,47	0	904	879
5							5	7	93	2			
0	Rincón	11	19		2,03	65,69	6,33	287	115,5	14,5	0	173	1,73
5					2	6	3		85	79			2
1	Cauchari	5	11		1,74	83,88	4,75	860	130,8	12,3	0	442	2,15
5					6	6	7		67	06			8
2	Olaroz	10	15		2,00	98,84	6,22	1,01	180,7	10,0	0	344	2,53
					2	6	4	4	98	77			3

5					20,42	1,46		32,30	6,63			
3	Jama	10	32	527	228	4	9	82	6	3	0	309 983
5			10	1,52	1,06	73,25	4,13		126,6	2,08		
4	Salinas Granes	10	7	0	8	5	5	332	63	2	0	314 447
5				1,57		28,03	16,6		185,4	11,3		
5	Guayatayoc	3	72		183	3	47	96	63	53	0	315 360

Table 4. Summary of mean, maximum (*max*), and concentration ratios of Li^+ and Mg^{2+} in brines from Andean salt pans. The * values for the Atacama brines follow Moraga et al. (1974), Ide and Kunasz (1989), and Kunasz (2006). The * mean Li^+ concentration for Olaroz is from García et al. (2019). Remaining values and ratios correspond to data presented in Table 3.

N°	salt pan	mean Li^+ (mg L^{-1})	mean Mg^{2+} (mg L^{-1})	<i>max</i> Li^+ (mg L^{-1})	<i>max</i> Mg^{2+} (mg L^{-1})	Mg:Li mean ratio	<i>max</i> :mean Li ratio
1	Surire	359	2,291	540	3,830	6	2
2	Coipasa	252	12,211	416	23,000	47	2
3	Uyuni	715	15,533	4,720	75,300	22	7
4	Empexa	213	8,480	213	8,480	40	1
5	Huasco	160	1,964	480	5,880	12	3
6	Coposa	16	869	90	4,930	56	6
7	Michincha	<1	13	<1	25	641	2
8	Alconcha	<1	2	<1	2	16	1
9	Carcote	217	4,151	339	6,850	19	2
10	Ascotan	47	786	245	5,125	17	5
1	Pastos Grandes						
1	(Altiplano)	1,640	3,480	1,640	3,480	2	1
1		562 -		1,570 -	9,650 -		
2	Atacama	1,400*	4,064	6,400*	80,000*	7	3 - 5*
1	El Tara	140	165	420	440	1	3

3							
1	Aguas Calientes Norte	25	151	130	820	6	5
4							
1	Pujsa	89	376	400	3,762	4	5
5							
1	Loyoques	286	1,960	425	2,855	7	1
6							
1	Aguas Calientes Centro	15	946	45	7,981	63	3
7							
1	El Laco	37	2,372	101	6,250	64	3
8							
1	Aguas Calientes Sur	4	265	17	1,370	67	4
9							
2	Imilac	19	32	75	66	2	4
1							
2	Punta Negra	1	18	3	53	18	3
2							
2	Aguas Calientes Sur Sur	5	131	35	1,311	25	7
3							
2	Pajonales	25	1,560	62	5,200	63	3
4							
2	La Azufrera	31	34,400	86	48,640	562	1
5							
2	Gorbea	316	26,810	500	4,225	85	2
6							
2	Ignorados	2	576	2	707	339	1
7							
2	Aguas Amarga	60	2,411	157	39,500	40	3
8							
2	Aguilar	367	6,600	375	6,900	18	1
9							
3	La Isla	402	2,578	1,150	8,300	6	3
0							
3	Las Parinas	130	1,185	400	3,600	9	3
2							
3	Pedernales	3	47	3	58	15	1

4						
3	Maricunga	36	252	92	680	3
8						
3	Incahuasi	95	11,214	145	15,896	2
9						
4	Antofalla-Botijuelas	209	577	615	816	3
0						
4	Rio Grande	398	2,161	692	2,234	2
1						
4	Arizaro	188	2,082	465	7,736	2
2						
4	Hombre Muerto	628	954	1,013	1,915	2
3						
4	Diablillos	180	1,226	557	1,884	2
4						
4	Ratones	158	223	260	323	2
5						
4	Centenario	288	2,293	1,020	7,550	4
6						
4	Pocitos-Quirón	60	655	101	1,384	2
7						
4	Pozuelos	401	1,641	940	2,587	2
8						
4	Pastos Grandes (Puna)	476	4,155	857	5,647	2
9						
5	Rincon	287	2,032	651	2,297	2
0						
5	Cacuhari	860	1,746	1,740	2,104	2
1						
5	Olaroz	1,014 - 841 *	2,002	1,213	2,301	1
2						
5	Jama	82	228	262	492	3
3						
5	Salinas Grandes	332	1,068	1,018	2,289	3
4						
5	Guayatayoc	96	183	125	183	1

Highlights

- Sizes of Andean salt pans are proportional to the extent of their endorheic basin.
- The equation $\text{mean Li} \approx \frac{1}{2} \text{max Li}$ is a tool for surveying of brine-type deposits.
- The greatest Li levels are expected to be found in largest and oldest salt pans.