ALS Methods:
ME-MS89L™
ME-ICP89
ME-ICP82b
Li-ICP41
Li-ICP61
Li-OG63
ME-MS14b™
ME-ICP15

Lithium

An element with growing interest due to modern technology applications.

Lithium is the lightest metal on earth, with an atomic number of 3 and atomic mass of 6.94. It has a high heat capacity and electrochemical potential which makes it ideal for technology involving heat transfer such as welding and metallurgical applications. Its chemical properties, light weight and high electrochemical potential also make it highly desirable for batteries allowing lithium batteries to hold three times the energy of nickel hydride at one-third of the weight. Lithium batteries also operate at very low temperatures with a longer battery life.

Lithium is concentrated by magmatic fractional crystalisation and partial melting which results in higher concentrations in some pegmatites and muscovite-bearing granites. During rock weathering highly soluble lithium is taken into solution and transported with water. Locations where water is trapped inland under arid conditions concentrate the lithium into residual brines. These concentration mechanisms have formed the two deposit types; pegmatites and continental lithium brines in closed basins, which are the source of most mined lithium. Other sources of viable lithium resources include geothermal brines, oilfield brines, and clay minerals such as hectorite and jadarite (Evans, 2013). Lithium is also often produced as a by-product from potash operations.

Smith et al. (1987) describe a lateritic soil anomaly up to 20km from Greenbushes which is a 3km long and several hundred meters wide pegmatite. The 12 by 20km distal anomaly contained the elements As, Be, Sb, and Sn, with a more proximal 1 by 5 km anomaly containing an assemblage of Nb, Ta and B. Exploration for lithium may also be aided by the pathfinder geochemistry of K, Mg, B, F, Na, Ca, Li/K and Li/Mg ratios. Where lithium is found in trace concentrations it substitutes for other metals rather than forming distinct lithium minerals. The most common substitution is for Mg^{2+} , the ion closest in size to lithium. Thus, by comparing the ratio of Li to Mg increased Li substitution can be identified. All elements of interest are reported from ME-MS89L™, except F which cannot be determined as hydrofluoric (HF) acid is part of the analytical process.

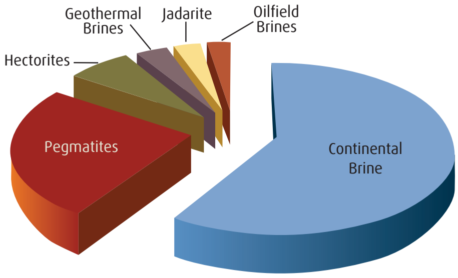
Brine water samples may also be analyzed for general chemistry including pH, conductivity, alkalinity, total dissolved solids, and Cl or Br. Vegetation samples show anomalous lithium in response to elevated groundwater, and indicator species may provide a useful exploration medium (Cannon, 1975).

Enriched brine occurrences require three factors for economic accumulation: an enriched Li host source rock, a transport mechanism, and concentration, trapping or sorption mechanism. Exploration considerations should include Li-enriched sources such as differentiated rhyolitic or granitic terrane, a groundwater or gaseous mechanism for Li transport and accumulation, and concentration or trapping via evaporation or clay sorption.

Lithium Background Concentrations:

- Natural waters: 1-3 ppb
- Sea water: 170 ppb
- Shales: 66 ppm
- Deep-sea clays: 57 ppm
- Soil samples: 20-200 ppm depending upon underlying host rock
- Ultramafic rocks: 0.5 ppm
- Granitic rocks: 40-100 ppm
- Micaceous schists: 50-200 ppm
- Pegmatites: 100-2,000 ppm
- Continental brines: 50 ppb-2,000 ppm
- Great Salt Lake: 60 ppm Li
- Salton Sea: 200 ppm Li
- Chabyer salt-lake: 0.12% Li
- Salar de Atacama: 200 ppm-0.18% Li

ALS offers a range of methods that are suitable for all matrix types and at all stages of a project, from exploration to resource definition and grade control. For assistance choosing the correct analytical method for your requirements



Geologic Source of Global Lithium Resource. Estimates from Keith Evans (2009).

please contact your local client services department at ALS. When submitting your samples please indicate that the commodity target is lithium, particularly when selecting multi-element packages. This allows ALS to insert lithium-specific Certified Reference Materials for the highest quality results and transparency in lab performance.

References:

- *Cannon, H.L., Harms, T.F., and Hamilton, J.C. 1975. Lithium in Unconsolidated sediments and plants of the Basin and Range Province, Southern California and Nevada. Geological Survey Professional Paper 918. Department of the Interior.*
- *Evans, R.K., 2009. Lithium. in Lithium Supply and Markets. Conference: Industrial Minerals magazine. Santiago, Chile.*
- *Evans, R.K., 2013. Lithium, chap. 10 in Gunn, G, ed., Critical Metals Handbook. Wiley, pp. 230-260.*
- *Smith, R.E., Perdrix, J.L., and Davis, J.M., 1987, Dispersion into pisolitic laterite from the Greenbushes mineralized Sn-Ta pegmatite system, Western Australia: Journal of Geochemical Exploration, v. 28, nos. 1–3, p. 251–265.*

CODE	ANALYTES & RANGES	DESCRIPTION
ME-MS89L™	Li 2 ppm – 2.5%, Mg 0.01 – 30%; various other elements; MP* – 10%	Lowest detection limits using Na_2O_2 fusion and ALS's super trace ICP-MS methodology. A package suitable for exploration in pegmatites prospective for Li and accessory commodities. Boron may be added at an additional cost. The digestion and sample introduction is carried out with glass-free labware to avoid B contamination.
ME-ICP89	Li 0.001 – 10%; various other elements; MP – 7.5%	Economical exploration method for Li-bearing pegmatites using a Na_2O_2 fusion and ICP-AES finish. Includes all major elements and some key trace elements in addition to lithium.
ME-ICP82b	Li 0.002 – 10%, B 0.02 – 10%; MP – 5%	Low level ore grade Li and B by Na_2O_2 fusion and ICP-AES analysis. Ideal for jadarite and Li/B-bearing pegmatites.
Li-ICP41	Li 10 ppm – 1%; MP – 10%	Intermediate level Li analysis suitable for exploration of Li-bearing sediments, carbonates and evaporites. Aqua regia and ICP-AES finish, including Li-specific CRMs. Multi-element package also available.
Li-ICP61	Li 10 ppm – 1%; MP – 10%	Intermediate level Li analysis suitable for exploration of Li-bearing sediments. Four-acid digestion and ICP-AES finish, including Li-specific CRMs. Multi-element package also available.
Li-OG63	Li 0.01 – 10%; MP – 5%	Ore grade Li by specialized four-acid digestion and ICP-AES finish, with Li-specific CRMs. Best suited to Li-bearing silicate sediments.
ME-MS14b™	Li 0.1 – 10 mg/L; various other elements; MP – 10%	Trace level analysis of Li in brine samples, run as-is on the ICP-MS. If lab filtration or acidification is required, please indicate this on the submittal form.
ME-ICP15	Li 10 – 3,000 mg/L; various other elements; MP – 10%	Intermediate to high level analysis of Li and other elements in brine samples, run as-is on the ICP-MS. If acidification is required, please indicate this on the submittal form.

** MP – method precision.*

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