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XI SIMPÓSIO BRASILEIRO DE EXPLORAÇÃO MINERAL
XI BRAZILIAN SYMPOSIUM ON MINERAL EXPLORATION

Lithium ores in Eastern Brazilian Pegmatite Province: a review and new discoveries of spodumene-rich pegmatites (SRP)

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CNPq

INSTITUTO GEO ATLANTICO

UFMG CPMTC

LITHIUM IONIC

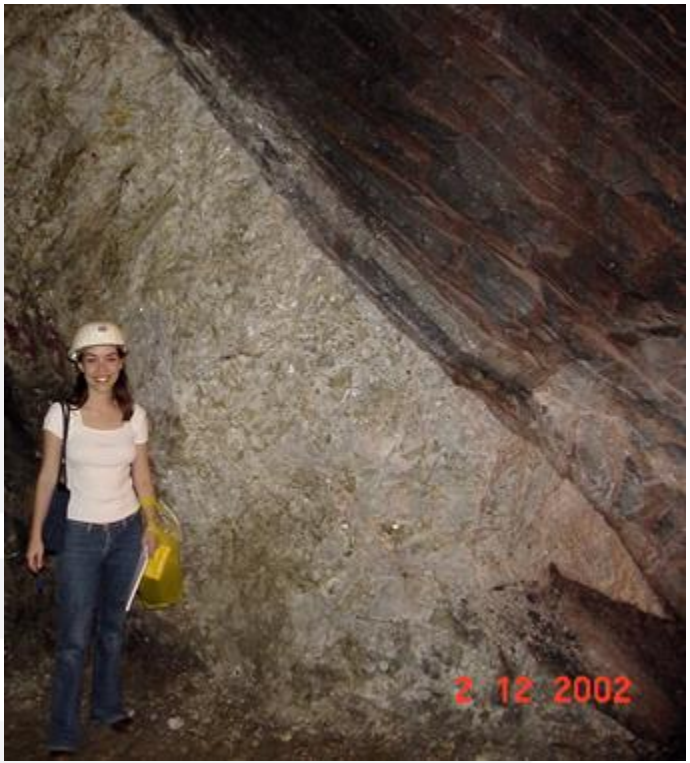
mglit

Bandeira deposit: typical drill core – Lithium Ionic

Spodumene-rich pegmatite ⇒ SRP

Spodumene + Albite + Quartz + K-feldspar > 90 vol%

Micas + Phosphates + Nb-Sn-Ta oxides + Petalite + … < 10 vol%



Cachoeira Mine – CBL

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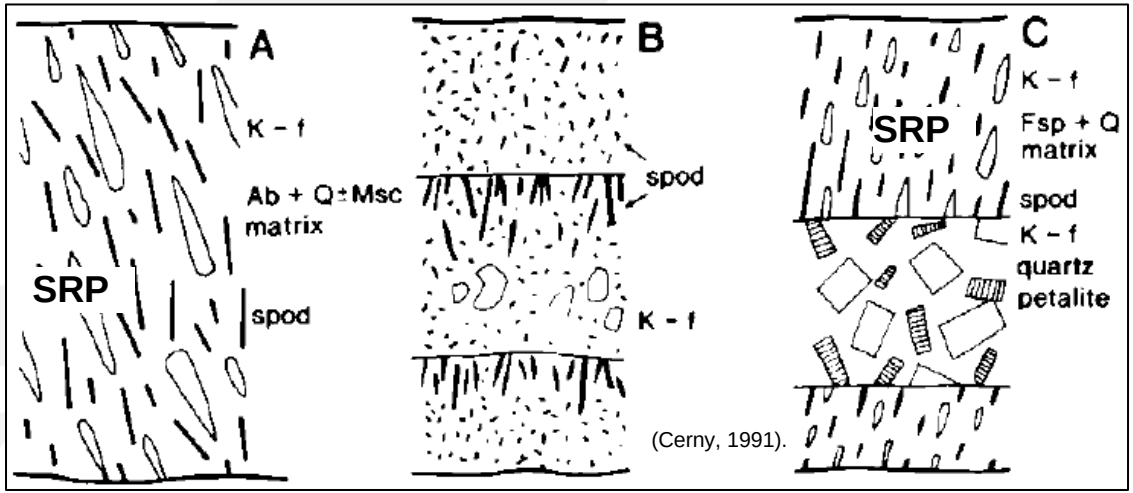
SRP

Unzoned to poorly zoned

but rather inequigranular!



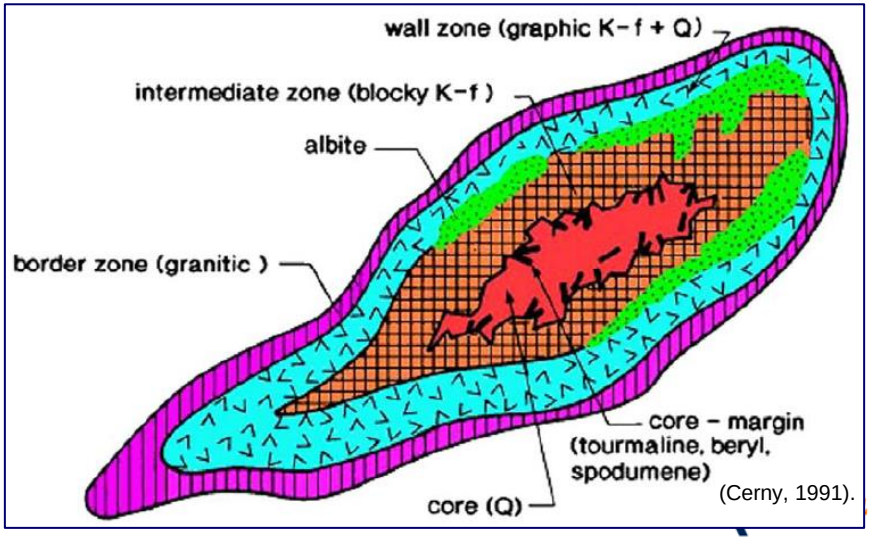
(Cerny, 1991).

LCT

Zoned to complex zoned:

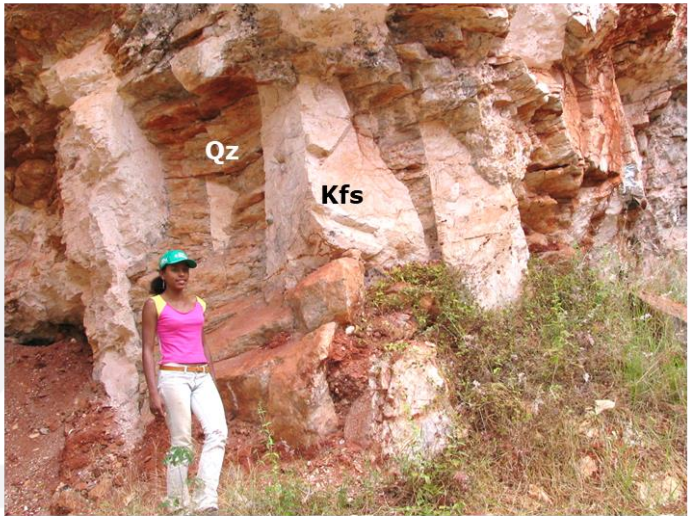
- primary crystallization zones: marginal, wall and intermediate zones, and quartz cores

- secondary units: fracture fillings, replacement bodies, cavities



(Cerny, 1991).

Zoning in LCT pegmatites

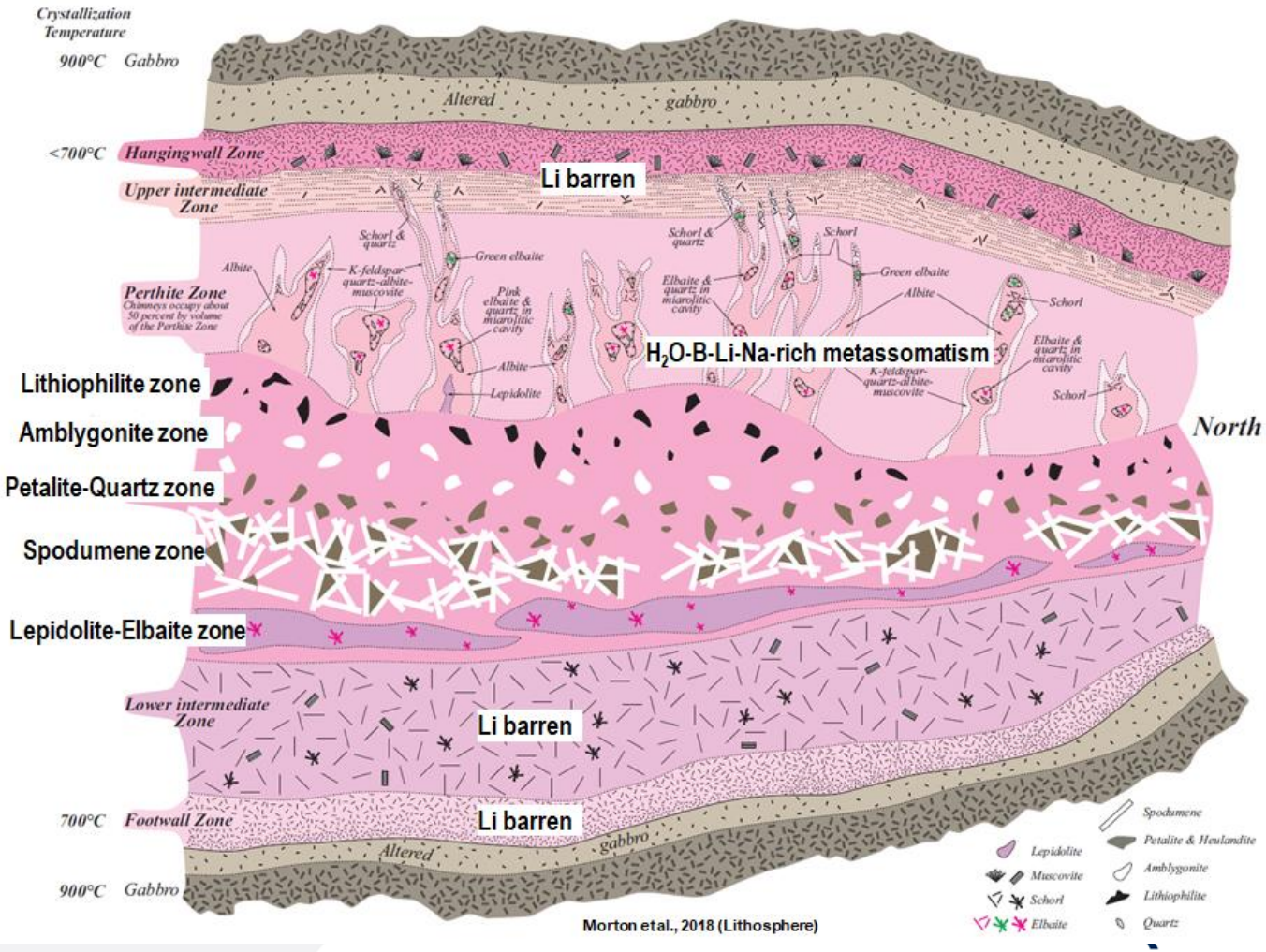


Graphic texture ⇒ **high viscosity at eutectic T: typical of granitic pegmatites generally poorer in lithium or with lithium minerals concentrated in very internal zone and core**

Complex LCT Stewart Pegmatite

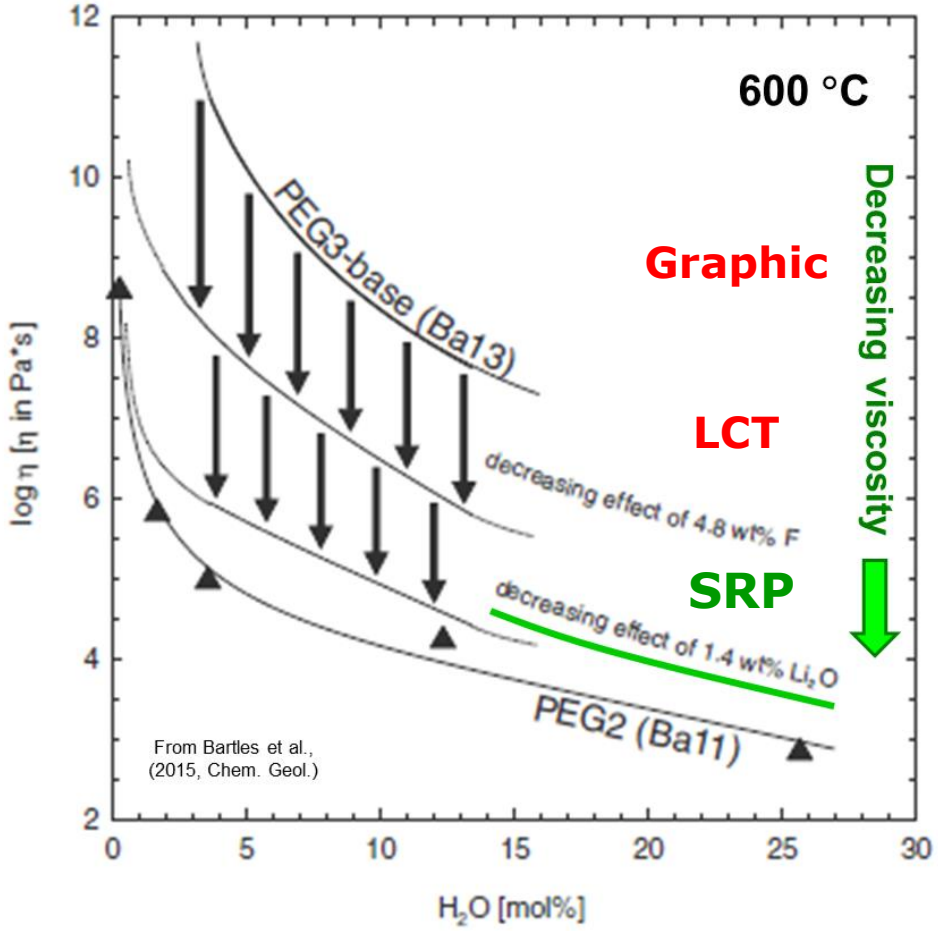
Pala, South California

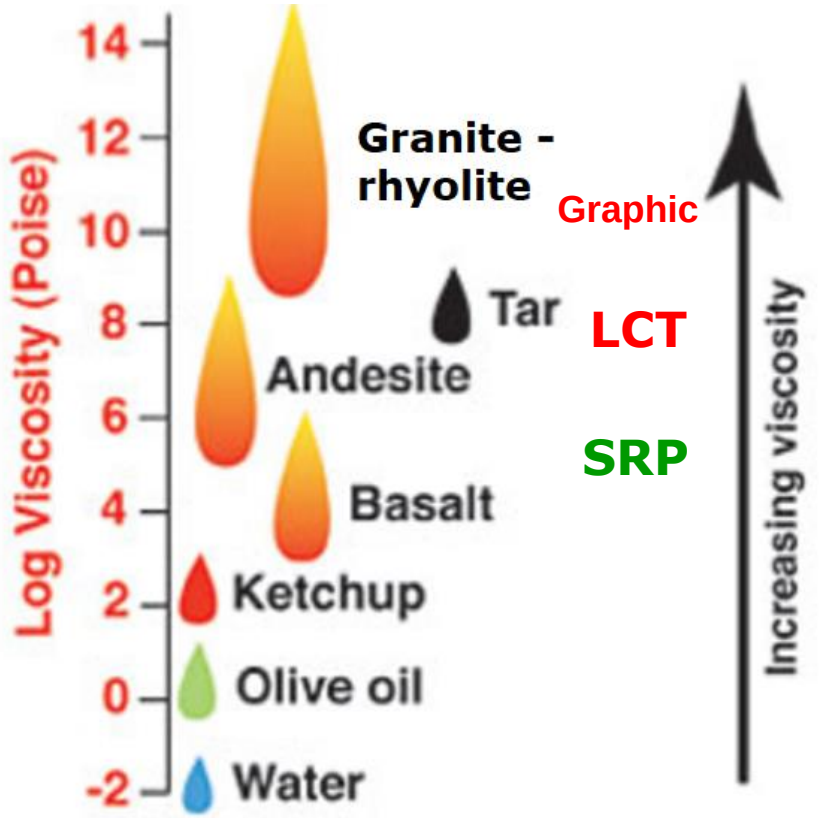
A thick (≤ 60m), complex, zoned, LCT pegmatite rich in Li-silicates and Li-phosphates



Morton et al., 2018 (Lithosphere)

Lithium: a powerful fluxing!



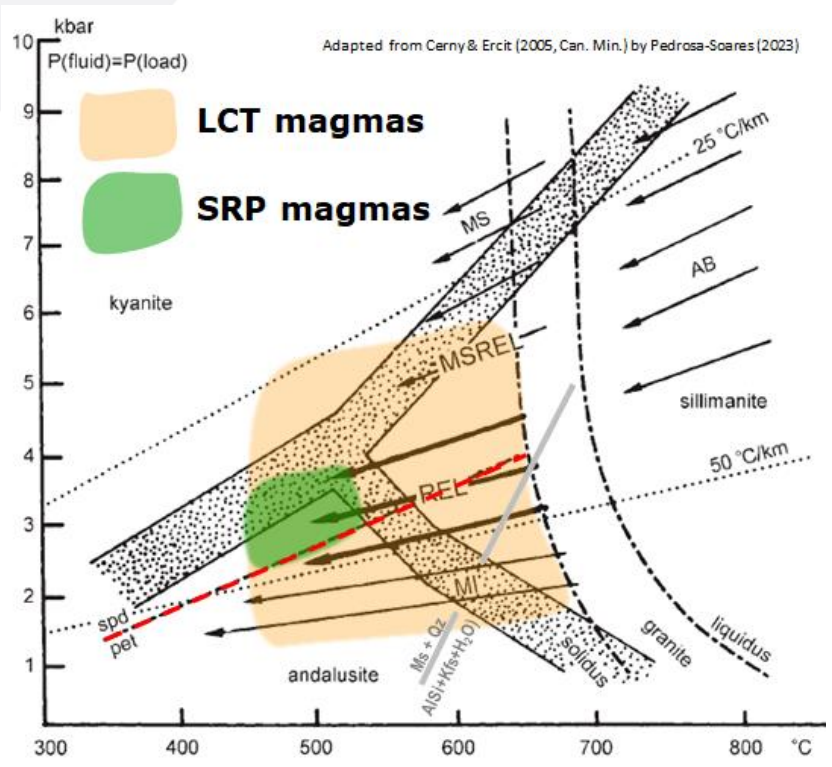


LCT versus SRP

Class	Subclass	Type	Subtype	Family
Abyssal	HREE			NYF
	LREE			
	U			NYF
	BBe			LCT
Muscovite				
Muscovite–rare element	REE			NYF
	Li			LCT
Rare element	REE	allanite–monazite		NYF
		euxenite		
		gadolinite		
	Li	beryl	beryl–columbite	LCT
			beryl–columbite–phosphate	
		complex	spodumene	
			petalite	
			lepidolite	
			elbaite	
			amblygonite	
		albite–spodumene	**SRP: Spodumene-rich pegmatites**	
		albite		
Miarolitic	REE	topaz–beryl		NYF
		gadolinite–fergusonite		
	Li	beryl–topaz		LCT
		spodumene		
		petalite		
		lepidolite		

Cerny et al., 2012; Elements

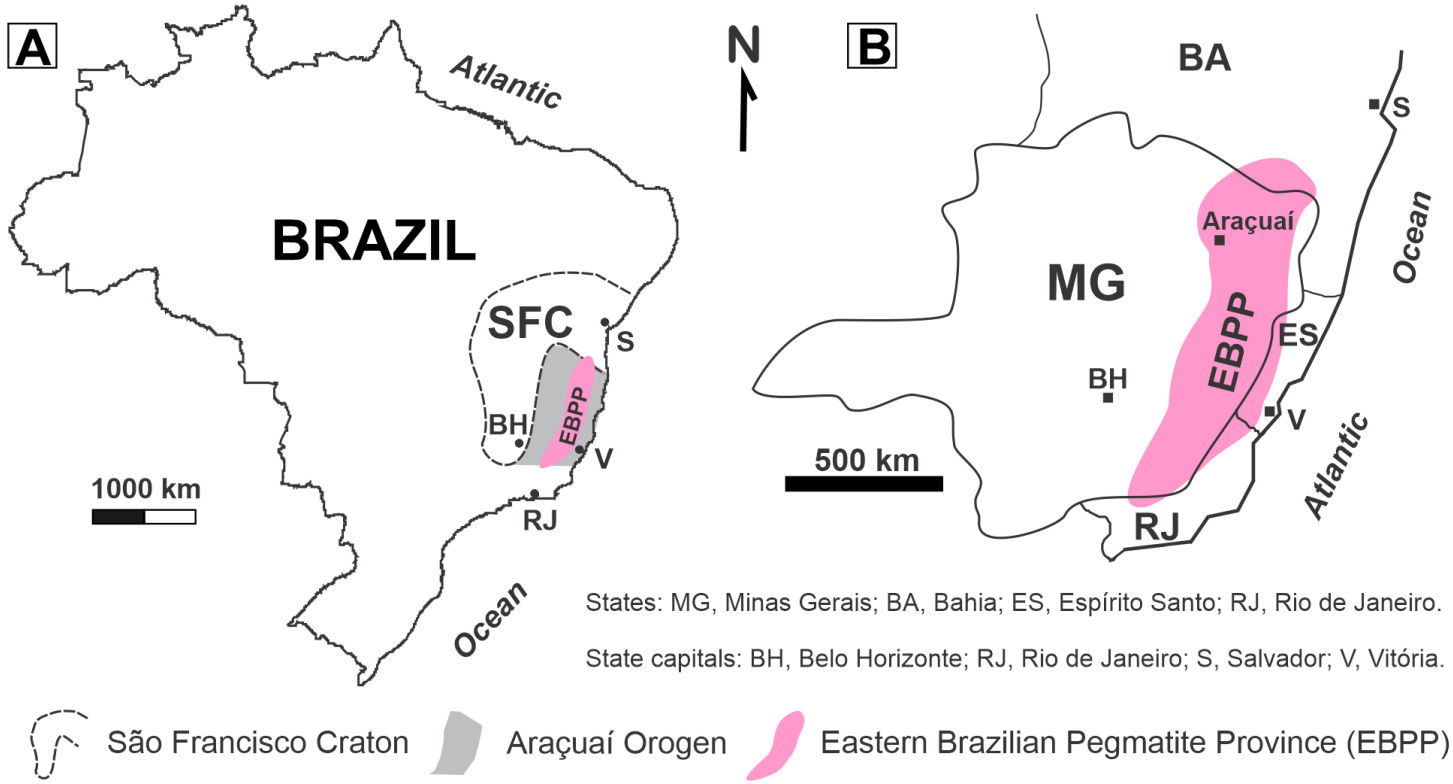
LCT = Lithium-Cesium-Tantalum; NYF = Niobium – Yttrium – Fluorine



CLASSIFICATION OF PEGMATITES OF THE RARE ELEMENT CLASS			
Pegmatite type	**Pegmatite subtype**	**Geochemical signature**	**Typical minerals**
RARE-EARTH	allanite-monazite	(L)REE, U, Th (P, Be, Nb > Ta)	allanite monazite
	gadolinite	Y, (H)REE, Be, Nb > Ta, F (U, Th, Ti, Zr)	gadolinite, fergusonite, euxenite, (beryl) (topaz)
BERYL	beryl-columbite	Be, Nb >< Ta (± Sn, B)	beryl columbite-tantalite
	beryl-columbite-phosphate	Be, Nb >< Ta, P (Li, F ± Sn, B)	Beryl, columbite-tantalite, triplite, triphylite
LCT **COMPLEX (rare element)**	spodumene	Li, Rb, Cs, Be, Ta >< Nb (Sn, P, F ± B)	spodumene (amblygonite) beryl (lepidolite) tantalite (pollucite)
	petalite	Li, Rb, Cs, Be, Ta > Nb (Sn, Ga, P, F ± B)	petalite (amblygonite) tantalite beryl (lepidolite)
	lepidolite	F, Li, Rb, Cs, Be Ta > Nb (Sn, P ± B)	lepidolite microlite beryl topaz (pollucite)
	amblygonite	P, F, Li, Rb, Cs Be, Ta > Nb (Sn ± B)	amblygonite (lepidolite) beryl (pollucite) tantalite
ALBITE-SPODUMENE	**SRP**	Li (Sn, Be, Ta >< Nb ± B)	spodumene (beryl) (cassiterite) (tantalite)
ALBITE		Ta >< Nb, Be (Li ± Sn, B)	tantalite (cassiterite) beryl

. Classification of pegmatites of the Rare-Element class. (Černý, 1991)

EBPP – Eastern Brazilian Pegmatite Province: 150,000 km²



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A VISIONARY MINING ENTREPRENEUR!

LITHIUM ORE IN BRAZIL

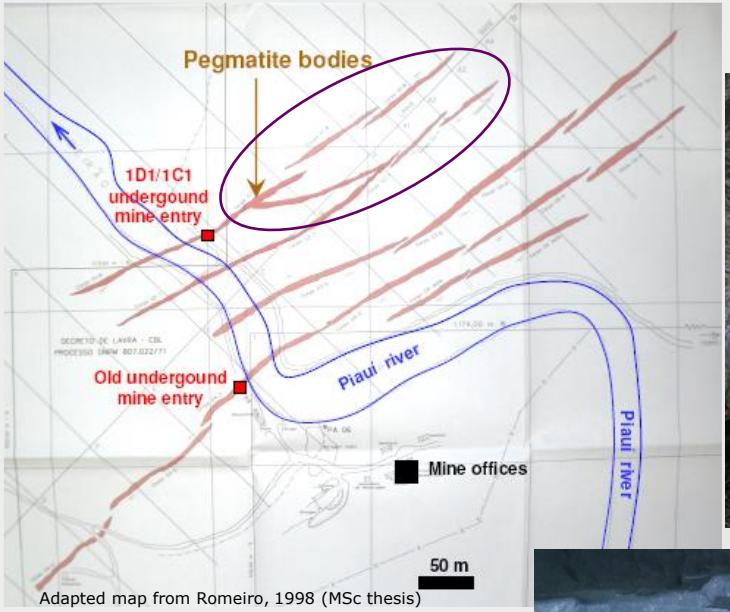
KHALIL AFGOUNI and J. H. SILVA SÁ

Arquena de Minerios Metais Ltd., Sãu Paulo, Brazil

(*Received* 10 *January* 1978)

power generation, the development of which is already underway in Brazil. Another new use is in lithium batteries for electric cars and, if this application becomes a reality, Brazil will be a big consumer, ranking at the same level as the most developed countries in the world, with the advantage of being one of the few countries capable of producing its own raw material.

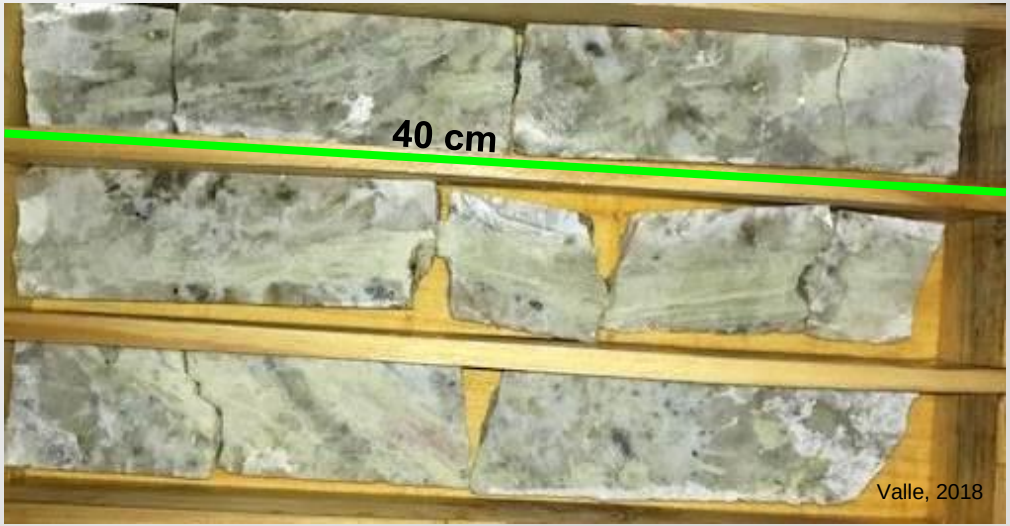
CBL – Cachoeira Mine – Since 1991

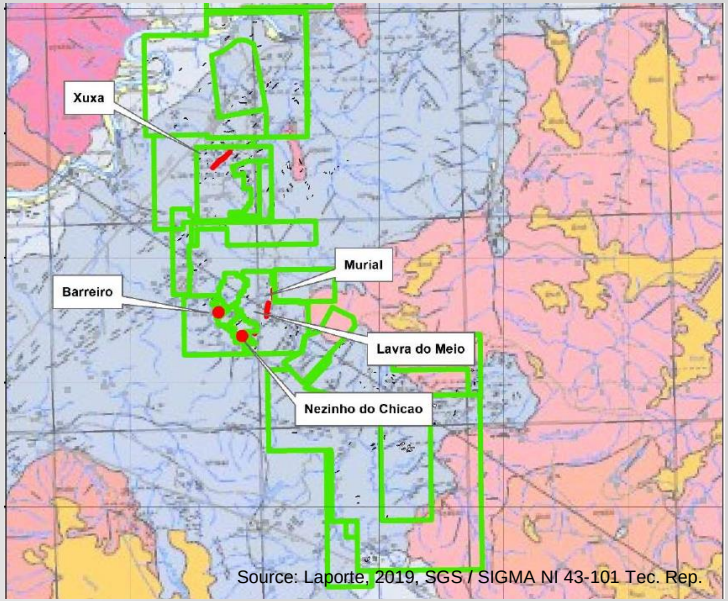


Adapted map from Romeiro, 1998 (MSc thesis)

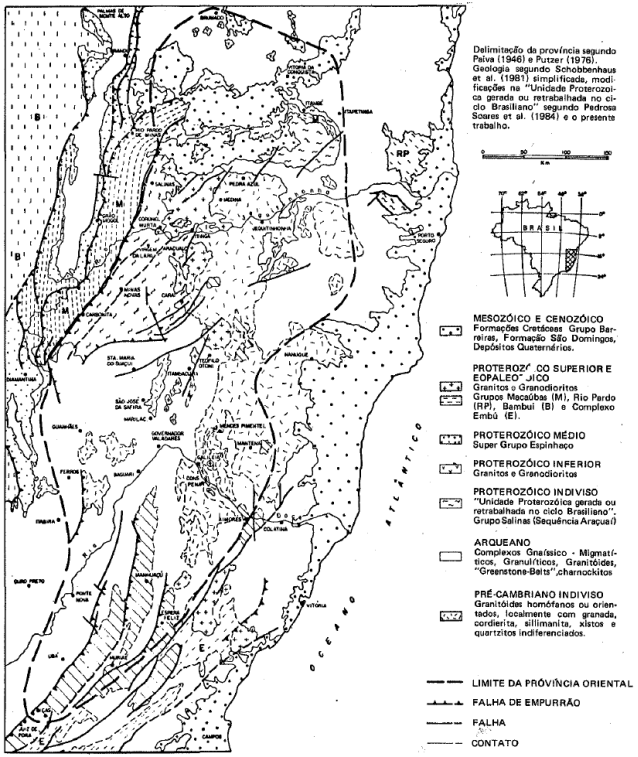
Swarm of unzoned spodumene-rich pegmatites (SRP)

Xuxa SRP: 1700m long x 13m thick x >300m downdip





Eastern Brazilian Pegmatite Province: after 1/2 century of mapping and studies



Correia-Neves, Pedrosa-Soares and Marciano, 1986, Rev.Bras.Geoc.

Area ~ 150.000 km²

Wholly mapped in 100,000 scale (by CPRM, UFMG-CODEMIG and UFMG-CPRM), and several more detailed mapped areas

> 800 bulk-rock chemical analysis

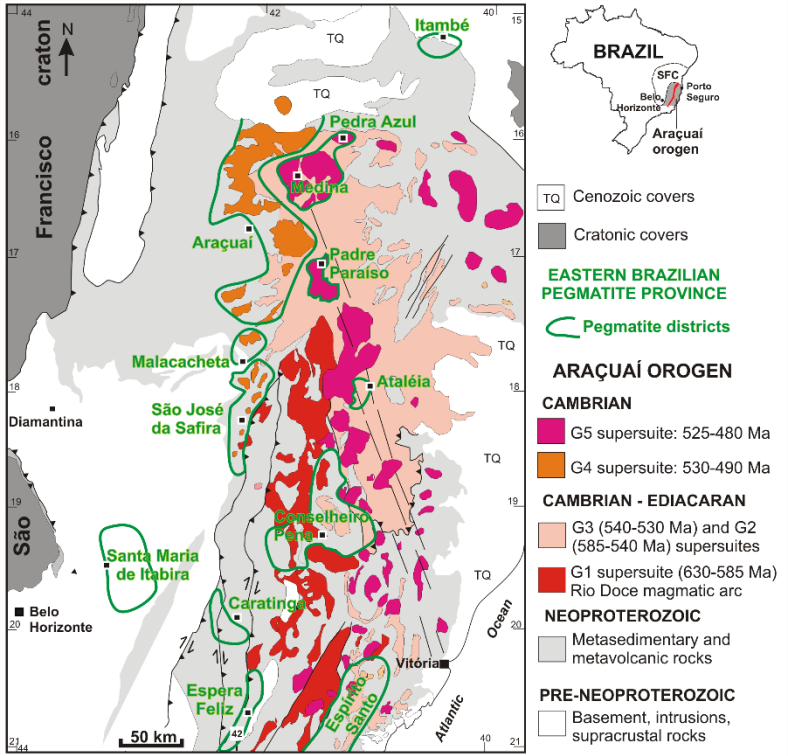
Thousands U-Pb, Rb-Sr, Sm-Nd and Lu-Hf isotope data

Thousands mineral chemistry analysis

Hundreds of pegmatites studied

Dozens of new mineral species discovered

> 500 x 10^6 tons of spodumene ore extracted and newly discovered



Modified from Pedrosa-Soares et al. 2011, G.S. London, Special papers

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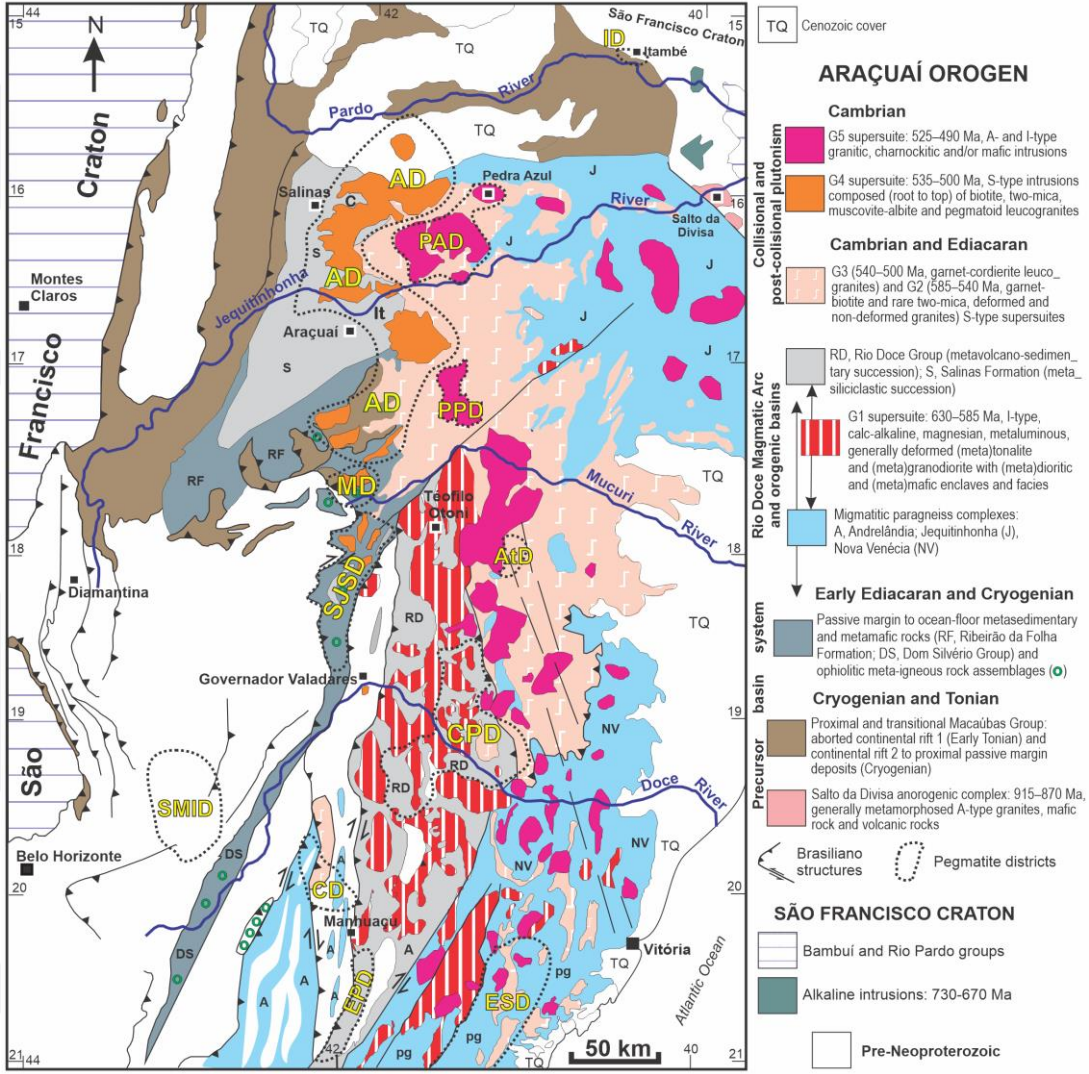
XI Brazilian Symposium on Mineral Exploration



“No rock is accidental!”*

*Lynn Fichter

No ore is unpredictable!

Araçuaí Orogen produced distinct pegmatite populations, (LCT, NYF, and SRP) forming the EBPP.

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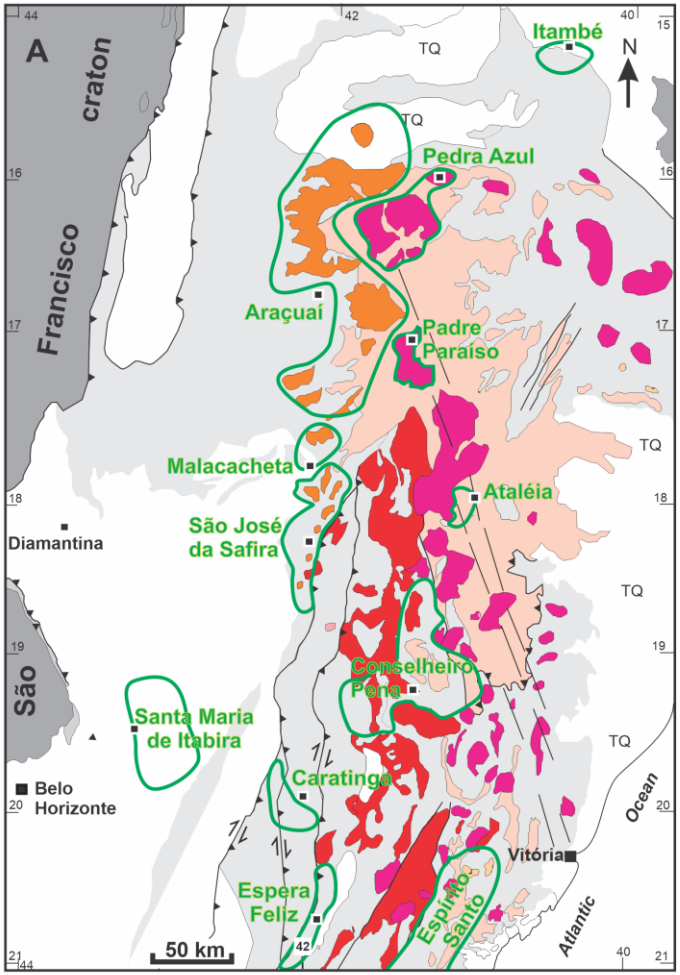


TQ Cenozoic covers

Cratonic covers

EASTERN BRAZILIAN PEGMATITE PROVINCE

Pegmatite districts

ARAÇUAÍ OROGEN

CAMBRIAN

G5 supersuite: 525-490 Ma

G4 supersuite: 535-490 Ma

CAMBRIAN - EDIACARAN

G3 (540-500 Ma) and G2 (585-540 Ma) supersuites

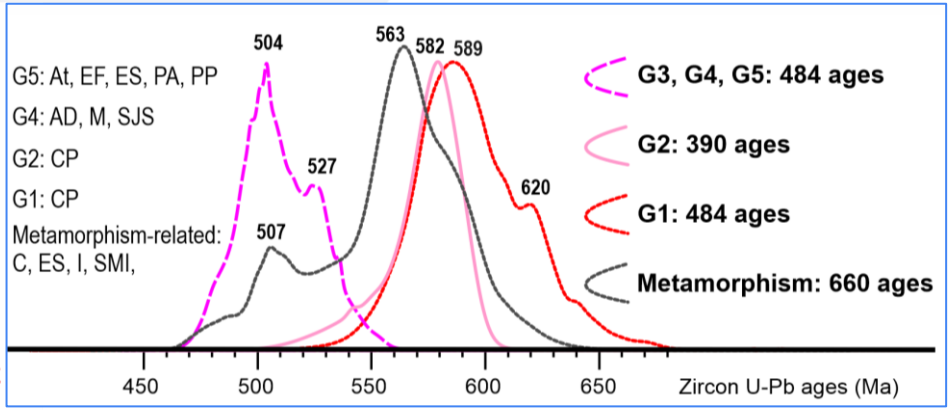
G1 supersuite (630-585 Ma) Rio Doce magmatic arc

NEOPROTEROZOIC

Metasedimentary and metavolcanic rocks

PRE-NEOPROTEROZOIC

Basement, intrusions, supracrustal rocks



12 pegmatite districts

distributed in time and space:

only FOUR have LCT pegmatites,

and only ONE has SRP.

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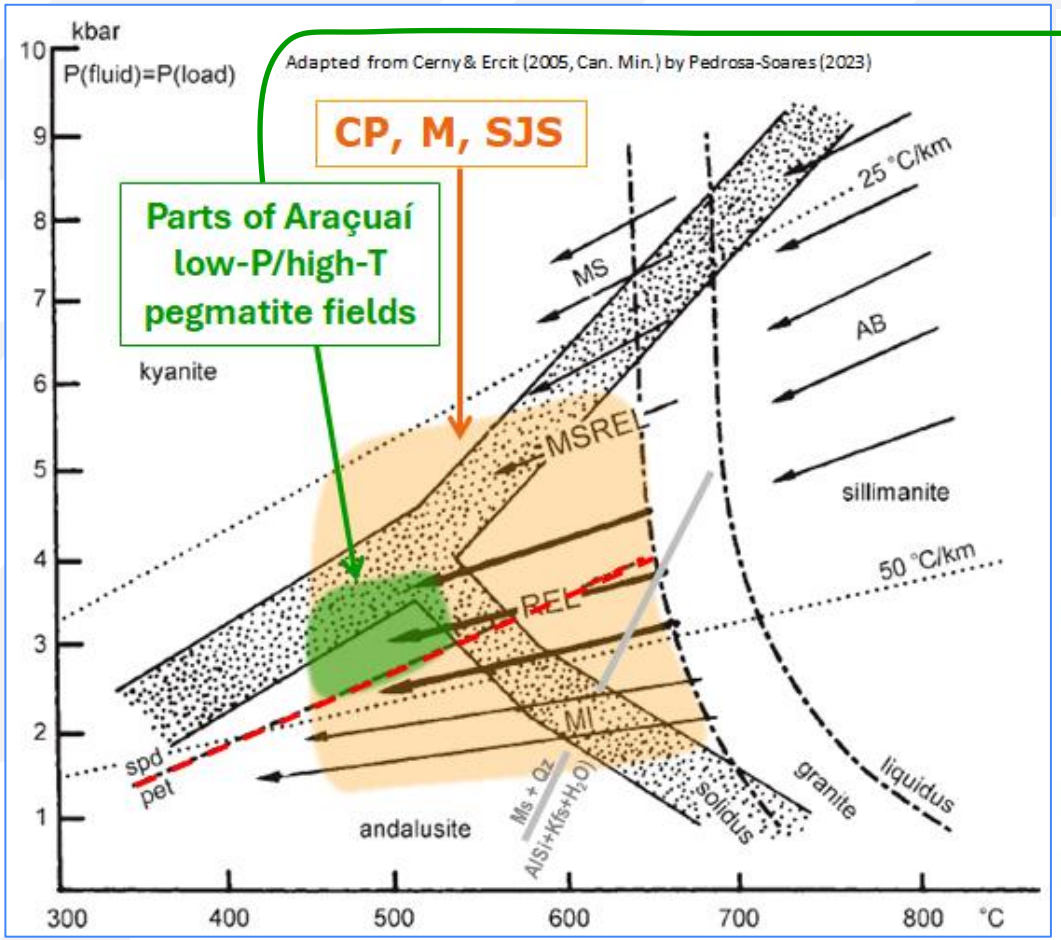
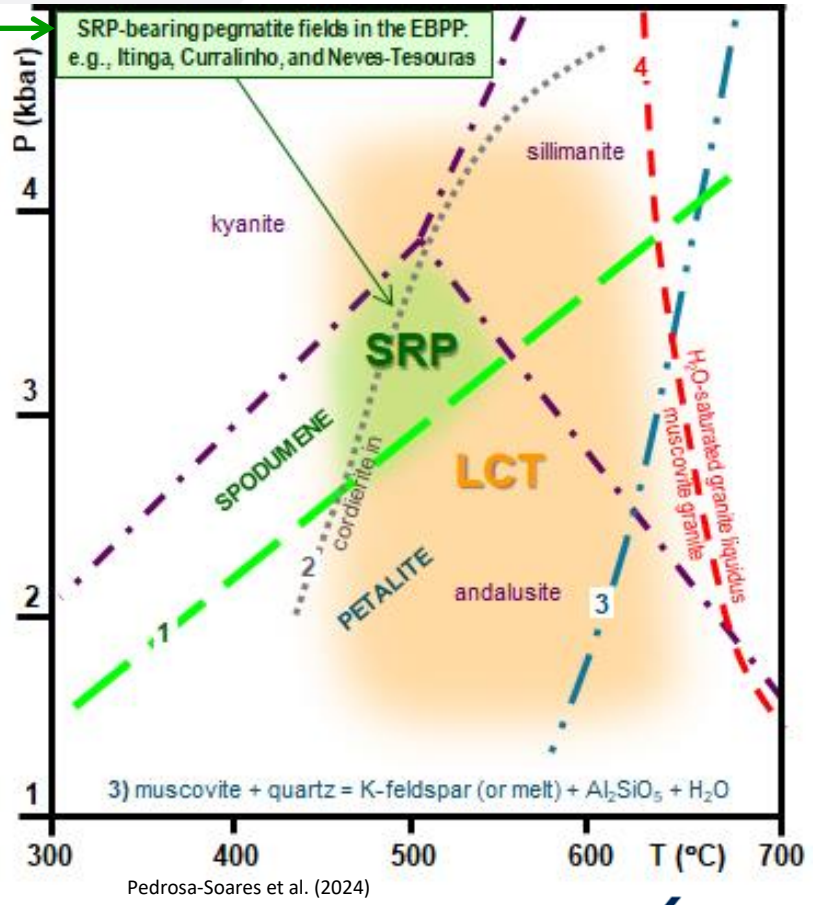
District	Production record, rare minerals	Pegmatite classification	Geology	Age (Ma)
Itambé	K-feldspar, quartz crystals, mica, beryl, columbite, monazite	anatectic; muscovite-rare element, REE, allanite-monazite, NYF	migmatitic biotite-hornblende gneisses and sillimanite-feldspar-mica schists; post-collisional	508
Pedra Azul	quartz, beryl (aquamarine), topaz	residual; REE, beryl-topaz, NYF	A-type G5 granite; post-collisional	501
Padre Paraíso	quartz, beryl (aquamarine), topaz, quartz crystals, goshenite, chrysoberyl	residual; REE, beryl-topaz, NYF	A- and I-types G5 granites and charnockites; post-collisional	519
Araçuaí	greenish to pinkish spodumene, petalite, lepidolite, Li-phosphates, cookeite, cassiterite, columbite-tantalite, industrial minerals (perthitic K-feldspar, albite, muscovite), tourmalines (elbaite, schorlite), beryl ore and gems (aquamarine, morganite), pollucite, quartz crystals, cleavelandite, herderite and other rare phosphates, topaz, bismuthinite	residual; mostly rare element and minor muscovite-rare element, Li, beryl, complex (spodumene, petalite, lepidolite, elbaite, amblygonite), albite-spodumene (SRP), albite, LCT	S-type G4 leucogranites; low-P/high-T (andalusite, cordierite, sillimanite) to medium-PT (garnet, staurolite, kyanite, sillimanite) mica schists to paragneisses, metasandstones, calc-silicate rocks, and meta-ultramafic rocks; post-collisional	510-500
Ataléia	quartz crystals, beryl (aquamarine), topaz, chrysoberyl	residual; REE, beryl-topaz, NYF	A- and I-types G5 granites and charnockites; post-collisional	502
S. José da Safira	tourmalines (elbaite, schorlite), industrial minerals (perthitic K-feldspar, albite, muscovite), beryl ore and gems (aquamarine, heliodor, morganite), lepidolite, Li-phosphates, spodumene, garnet, cleavelandite, columbite-tantalite, cassiterite, bertrandite, microlite, zircon, rare phosphates	residual; muscovite-rare element and rare element, Li, beryl, complex (elbaite, lepidolite, Li-phosphates, spodumene), LCT	S-type G4 and G2 leucogranites; medium-PT (garnet, staurolite, kyanite, sillimanite) mica schists to paragneisses, metasandstones, calc-silicate rocks, and meta-ultramafic rocks; mostly post-collisional, possibly also late collisional (G2)	545, 490
Conselheiro Pena	industrial minerals (perthitic K-feldspar, albite, muscovite), tourmalines (elbaite, schorlite), beryl ore and gems, spodumene (kunzite), lepidolite, Li-phosphates, quartz crystals, cleavelandite, columbite-tantalite, cassiterite, rare phosphates (arrojadite, barbosalite, brasilianite, childrenite, correianevesite, eosphorite, roscherite, vivianite, etc.)	residual; muscovite-rare element and rare element; Li, beryl, complex (elbaite, Li-phosphates, lepidolite, spodumene), LCT	S-type G2 (and I-type G1?) granites; medium-PT to intermediate low-P (garnet, staurolite, cordierite, kyanite, sillimanite), mica schists to paragneisses, metasandstones, calc-silicate rocks, and meta-ultramafic rocks; collisional (and pre-collisional?)	570-545
Malacacheta	muscovite, beryl, chrysoberyl; alexandrite, sapphire	residual; muscovite-rare element (and rare element?), beryl, LCT; and anatectic to hydrothermal processes	S-type G4 leucogranites; mica schists, meta-ultramafic rocks, and migmatites; post-collisional	535-500
S. Maria de Itabira	emerald, alexandrite, aquamarine, industrial beryl, mica, quartz	quartz-feldspathic hydrothermal deposits, and anatectic pegmatites	ultramafic schists, banded iron formations, migmatites; late collisional to post-collisional	545-500
Caratinga, Espera Feliz	kaolin, corundum (sapphire, ruby), beryl	anatectic; abyssal, ceramic	migmatitic paragneisses; collisional	570
	quartz crystals, beryl (aquamarine), topaz	residual; REE, beryl-topaz; NYF	G5 intrusions; post-collisional	500
Espírito Santo	beryl (aquamarine, heliodor), quartz (amethyst and others), topaz, chrysoberyl, euclase, monazite, rare tourmaline; kaolin	residual, beryl-topaz, allanite-monazite, REE, NYF; anatectic, ceramic	G5 intrusions, post-collisional; migmatitic paragneiss, collisional	570, 500





Pedrosa-Soares et al. (2024)

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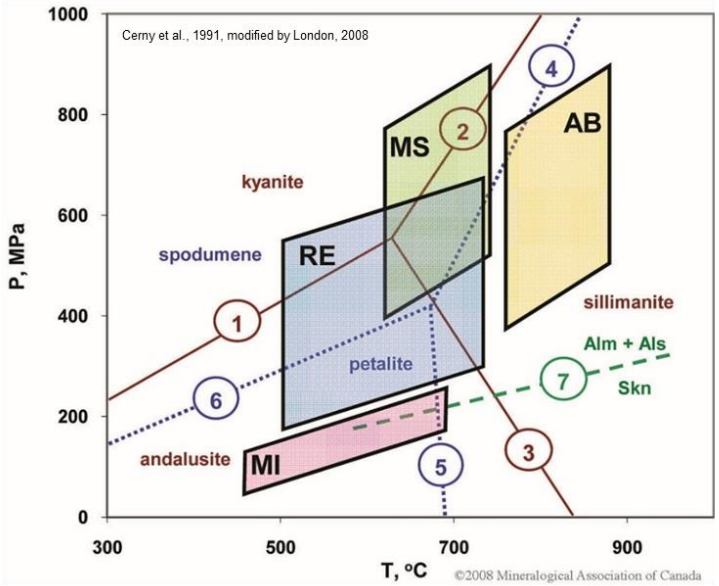
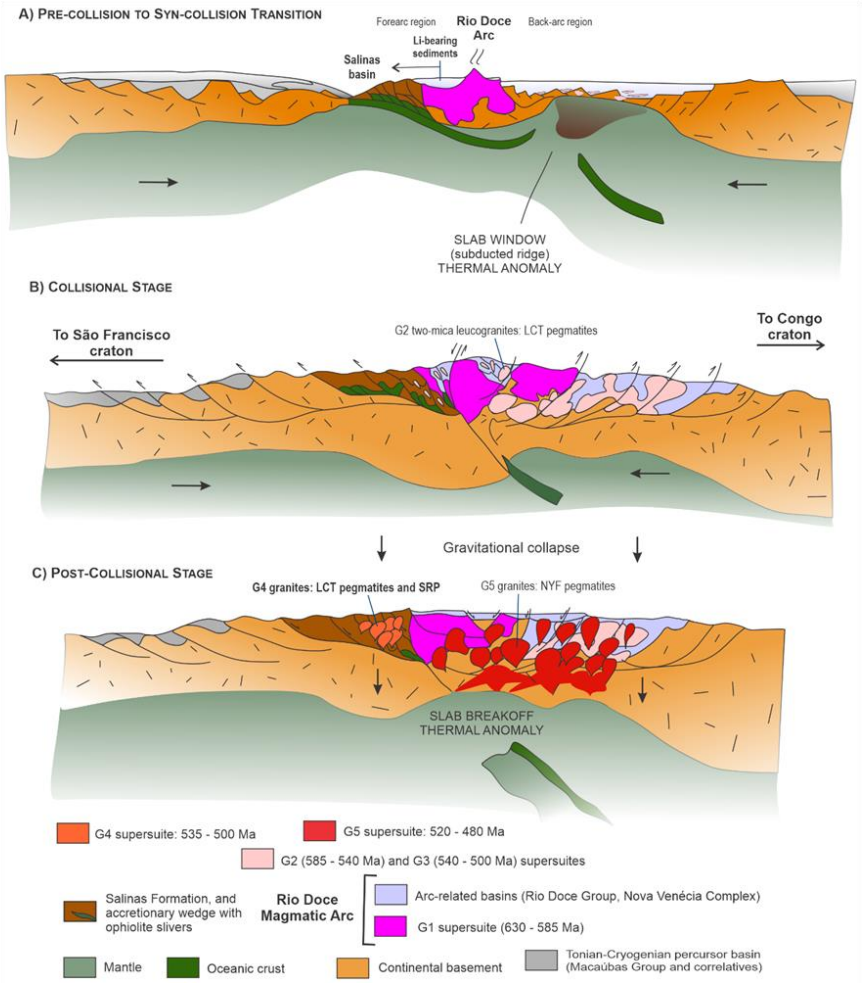
What do lithium-bearing brines and pegmatites have to do with subduction, magmatic arc, collision and gravitational collapse?

https://www.geologyforinvestors.com/brine-lithium-deposits/

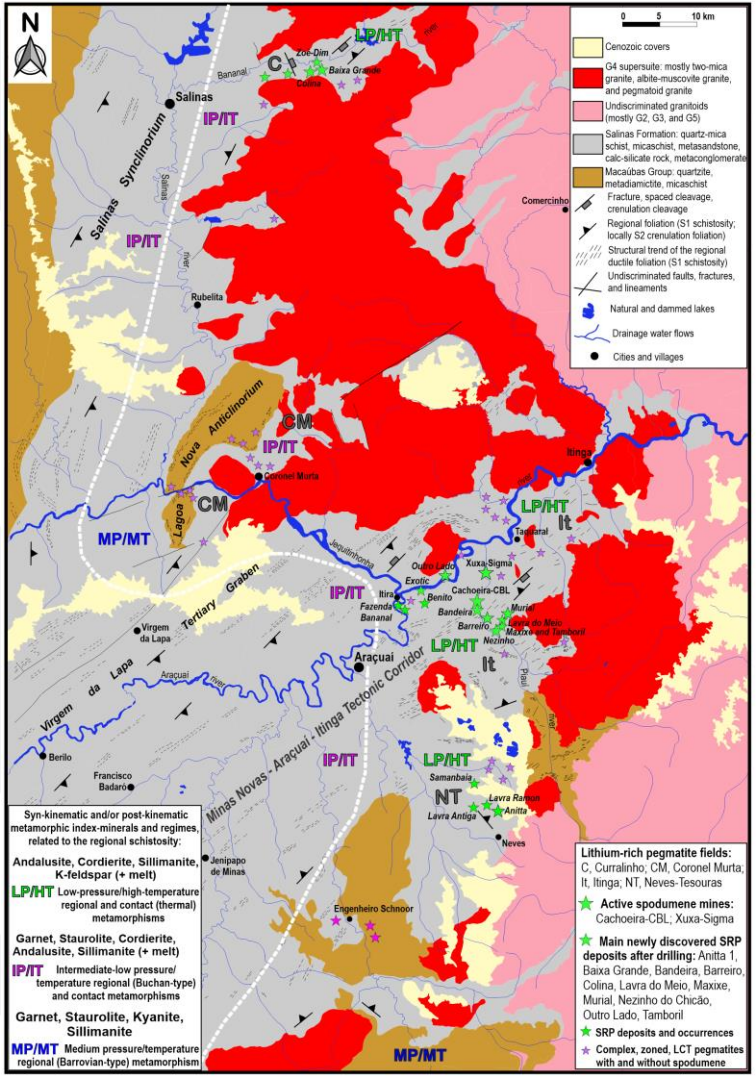




Lithium in brines and clay-rich sediments: Rio Doce Arc

Pegmatites: AB, MS, LCT: G2

Pegmatites: LCT: G4 SRP: G4 NYF: G5



New discoveries of SRP (s.s.)

Araçuaí Pegmatite District

Itinga and Curralinho pegmatite fields

G4 fertile granites

Low-P/high-T metamorphisms

Locally, SRP window (4-2.5 kbar at 550-450 °C)

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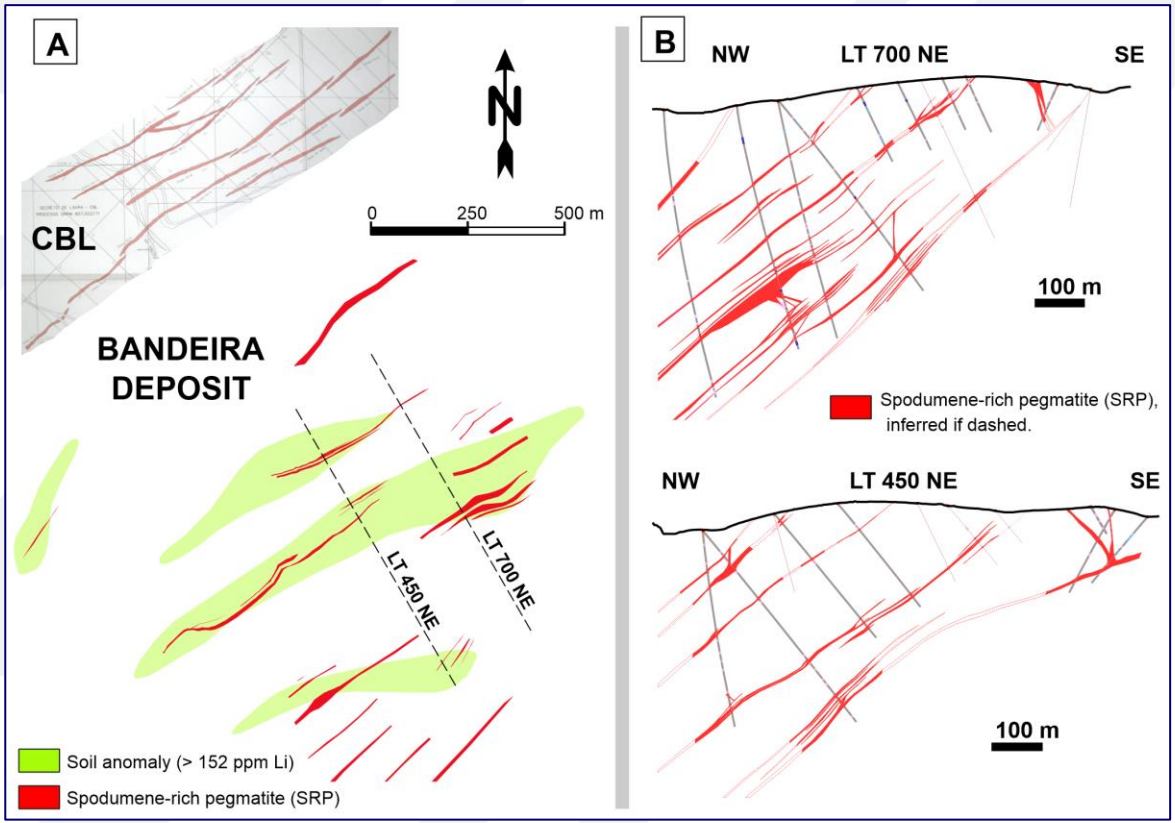
Cordierite-mica schist
Crd


Cordierite-mica schist with andalusite formed by contact metamorphism
And


G4 two-mica leucogranite

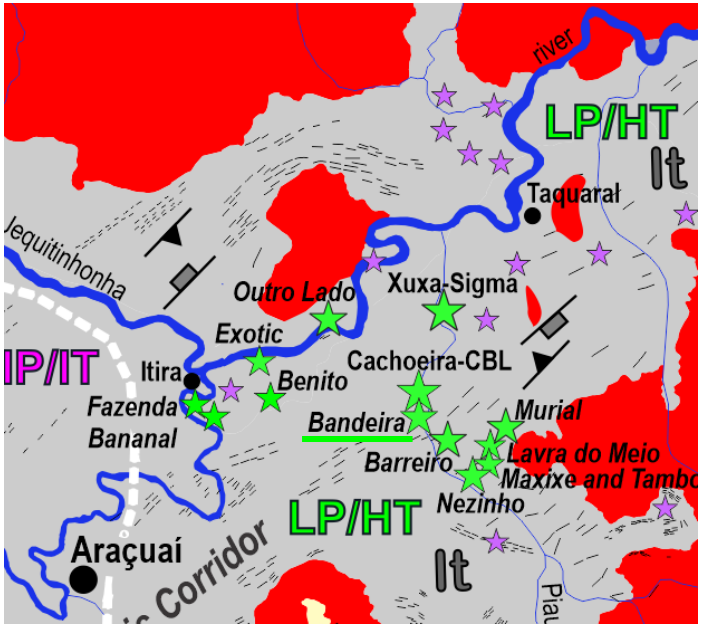
New discoveries of SRP (s.s.)



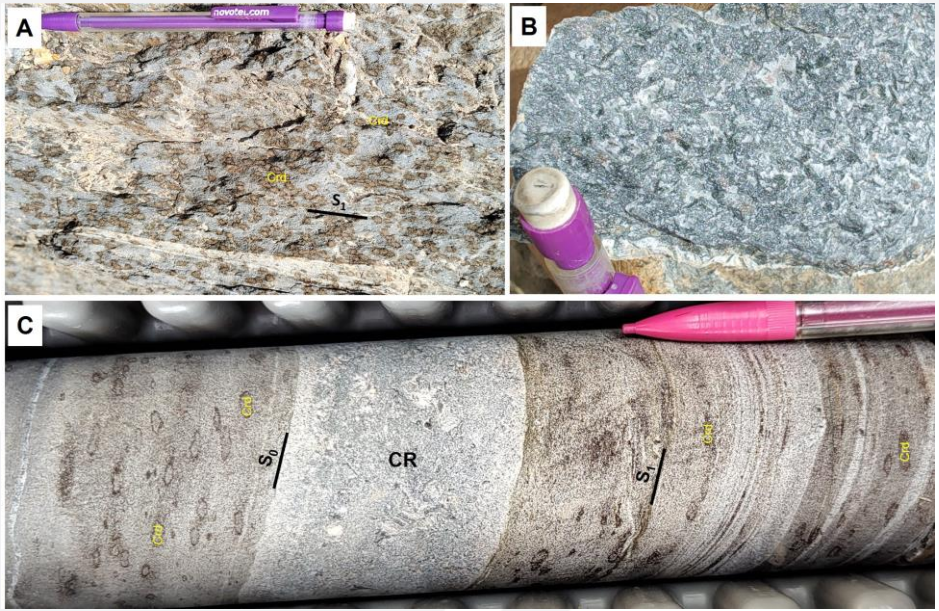
Source: https://www.lithiumionic.com/_resources/reports/30112023_PEA_GE21_Final.pdf?v=052310

Bandeira Deposit

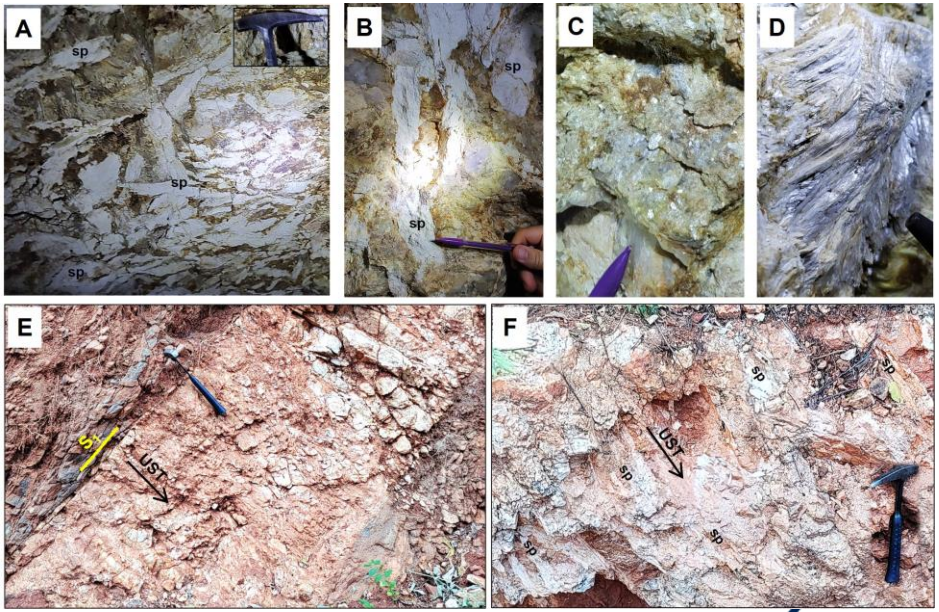
Lithium Ionic Corporation



Bandeira deposit host rocks:
A) Banded cordierite-mica schist (Crd, cordierite)
B) Calcsilicate rock
C) Drill core showing both host rocks (Crd, cordierite; CR, calcsilicate rock)

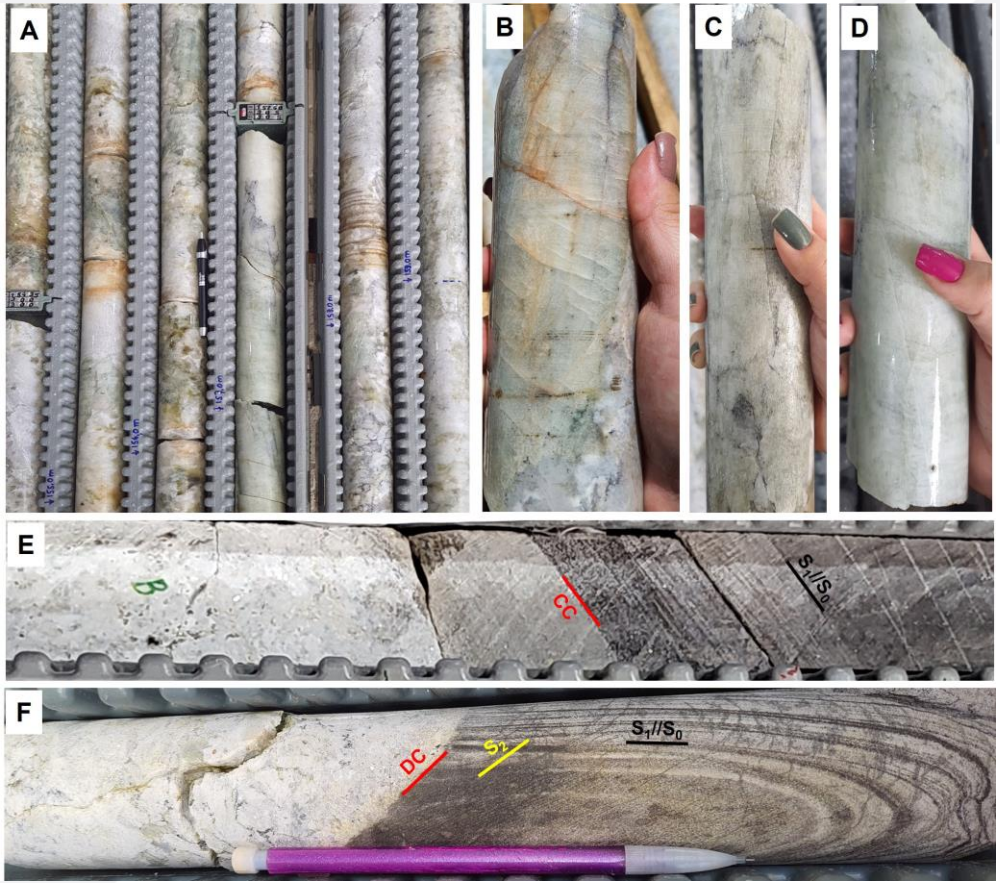


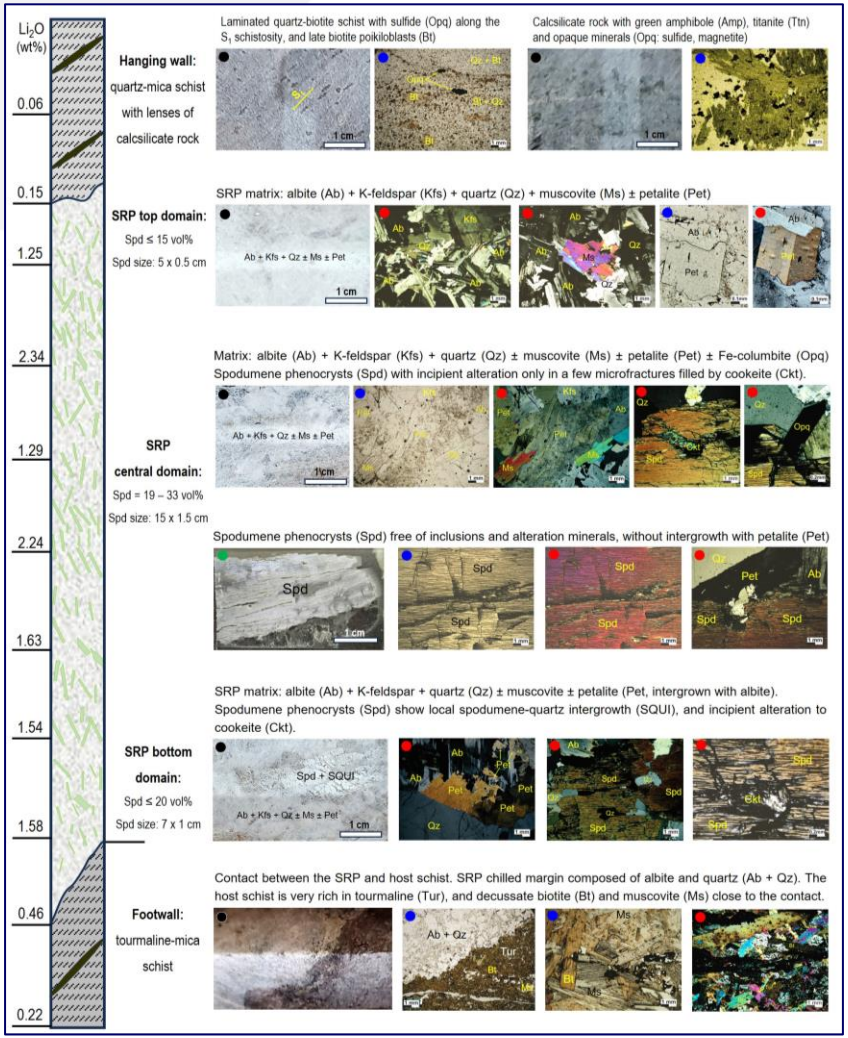
Bandeira exposures in an old digging (“shaft”, A to D) and the first trench:
A and B) Spodumene (sp) pseudomorphs altered to clay minerals;
C) and D) Li-mica in late metasomatic unit;
E and F) Concordant (to S1) contact of an SRP with unidirectional solidification texture (UST) outlined by partially weathered spodumene (sp)



Source: https://www.lithiumionic.com/_resources/reports/30112023_PEA_GE21_Final.pdf?v=052310

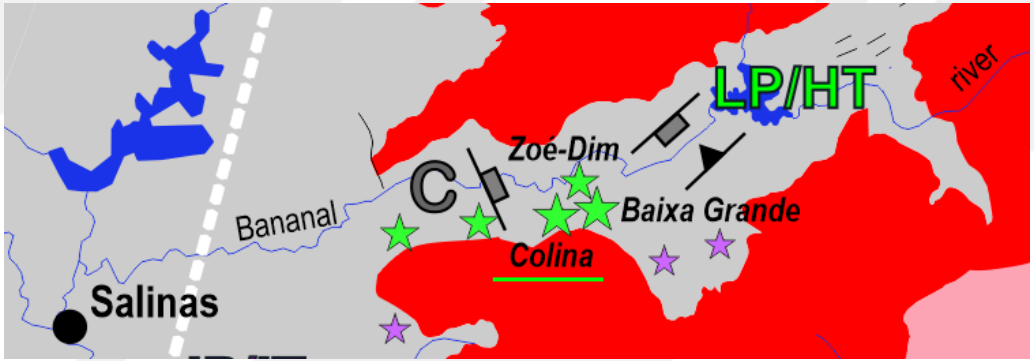
Typical unzoned SRP in the Bandeira Deposit (Lithium Ionic)





Source: https://www.lithiumionic.com/_resources/reports/30112023_PEA_GE21_Final.pdf?v=052310

New discoveries of SRP (s.s.)



Colina Deposit

Latin Resources – Salinas Project

The Colina SRP swarm (in a photo from an acrylic mockup)

See details in: https://www.latinresources.com.au/salinas-lithium-project-brazil/

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Thanks! Obrigado!

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