Geochemical and Isotopic Characterization of Callovian Continental Volcanogenic Deposits in the Minas Viejas Formation, Mexico*

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Abstract

The Minas Viejas Formation represents the first evidence of marine incursion into northeastern Mexico during the Jurassic, and consists of a succession of carbonates and gypsum, interbedded with volcanic and volcanoclastic deposits. In the area southwest of Galeana, Nuevo Leon, the stratigraphic succession is recognizable despite tectonic deformation, and some members are differentiated by sedimentological and petrological characteristics, fossil content and geochemical composition.

The La Primavera Member comprises a volcanic and volcanoclastic deposit of Callovian age, emplaced conformably within evaporites at the base of the Las Mulas Member of the Minas Viejas Formation. The regional tectonic setting in which La Primavera was deposited has been related to either rift-related volcanism or a continental volcanic arc. This work provides additional geochemical and isotopic information about the tectonic affinity of the La Primavera Member.

The pyroclastic volcanic unit exposed at La Mesita is composed of widely separated lenses of volcanic and volcanoclastic rocks; at the base its contact with the gypsum is sharp, irregular and apparently concordant, grading to laminated then to thin-bedded gypsum, volcanoclastic sandstone and siltstone. At the top of the section, it consists of a purple colored tuff with laminated carbonates and structureless gypsum. Petrologically it show a fine-grained groundmass composed of plagioclase with amphibole phenocrysts and alteration minerals such as chlorite and sericite.

Additional geochemical data on the classification based on immobile elements show that the La Primavera Member has an andesitic-trachyandesitic composition. Regarding its tectono-sedimentary depositional environment, the tectonic discrimination diagrams indicate an affinity with a continental volcanic arc. Multielement N-MORB and REE plots display an enrichment of Large Ion Lithophile Elements (LILE), and depletion of immobile elements, which are a common volcanic arc fingerprint. Strontium and neodymium isotopic data reinforce the evidence of a volcanic arc system as an origin of the La Primavera Member, possibly related to a late phase of a continental magmatic arc during the Callovian.

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Mexican Geological Survey

Minas Viejas Formation

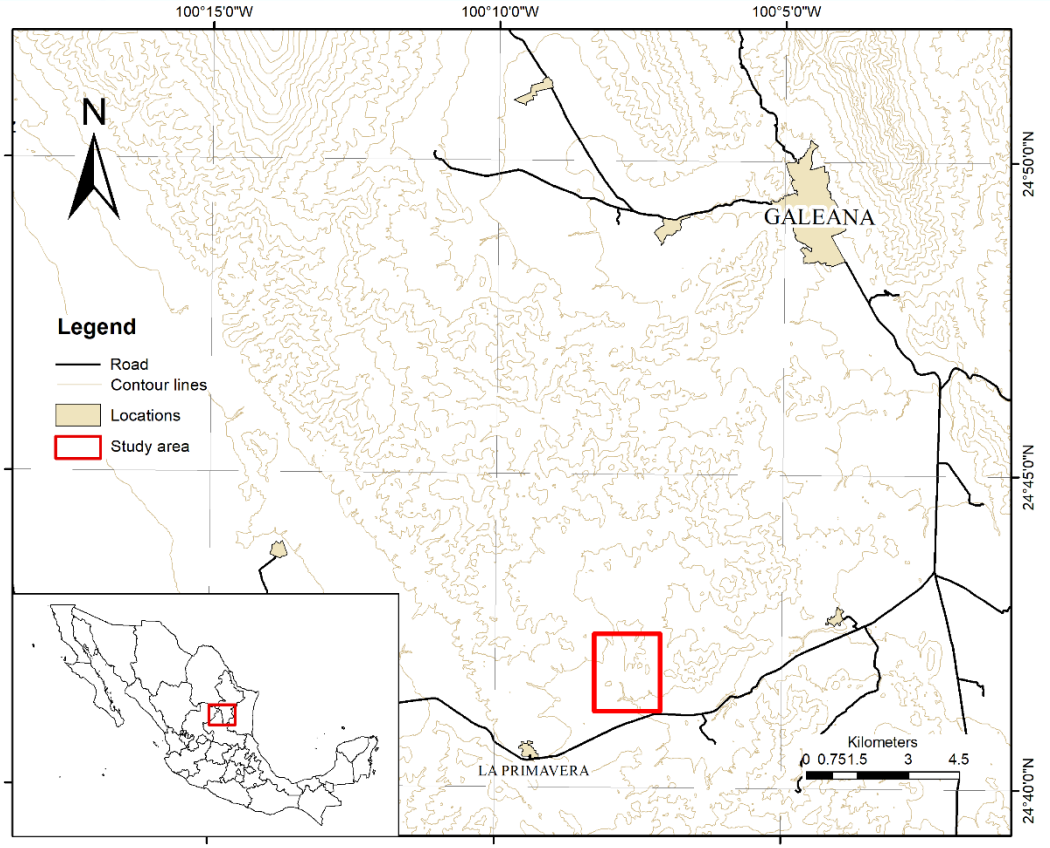
Formally introduced by Humphrey (1956) for a succession of gypsum, limestone, dolomite and intercalated siltstone.

In the area southwest of Galeana, Nuevo Leon, Minas Viejas Formation is well exposed and the stratigraphic succession is recognizable despite intense tectonic deformation.

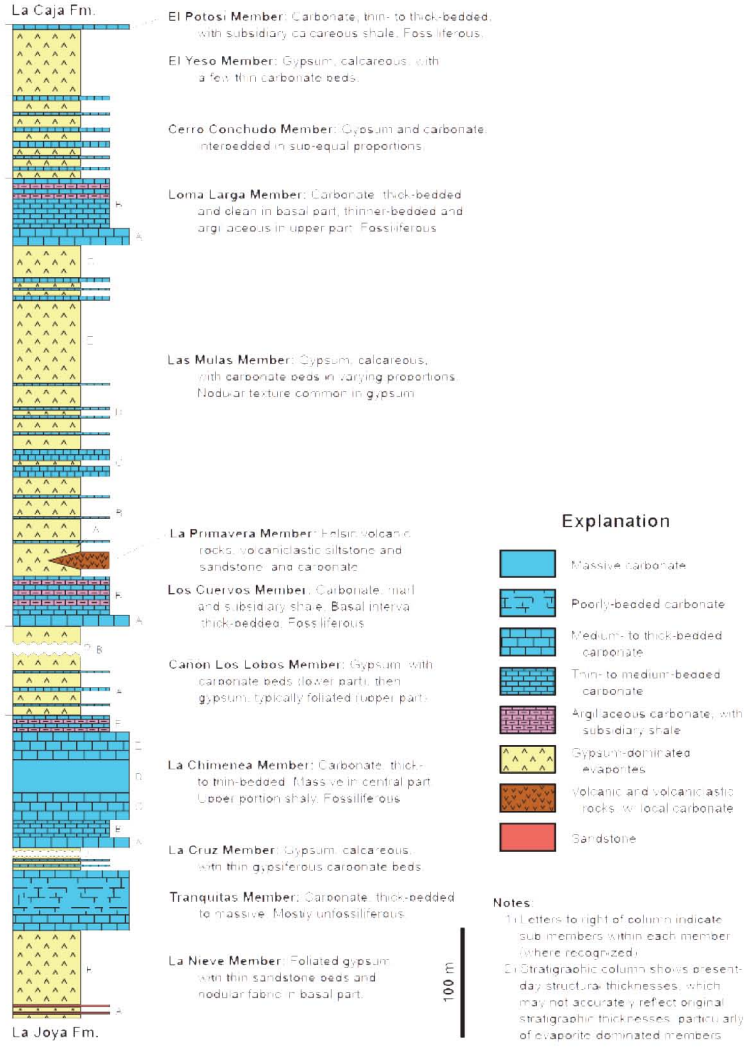
Study area

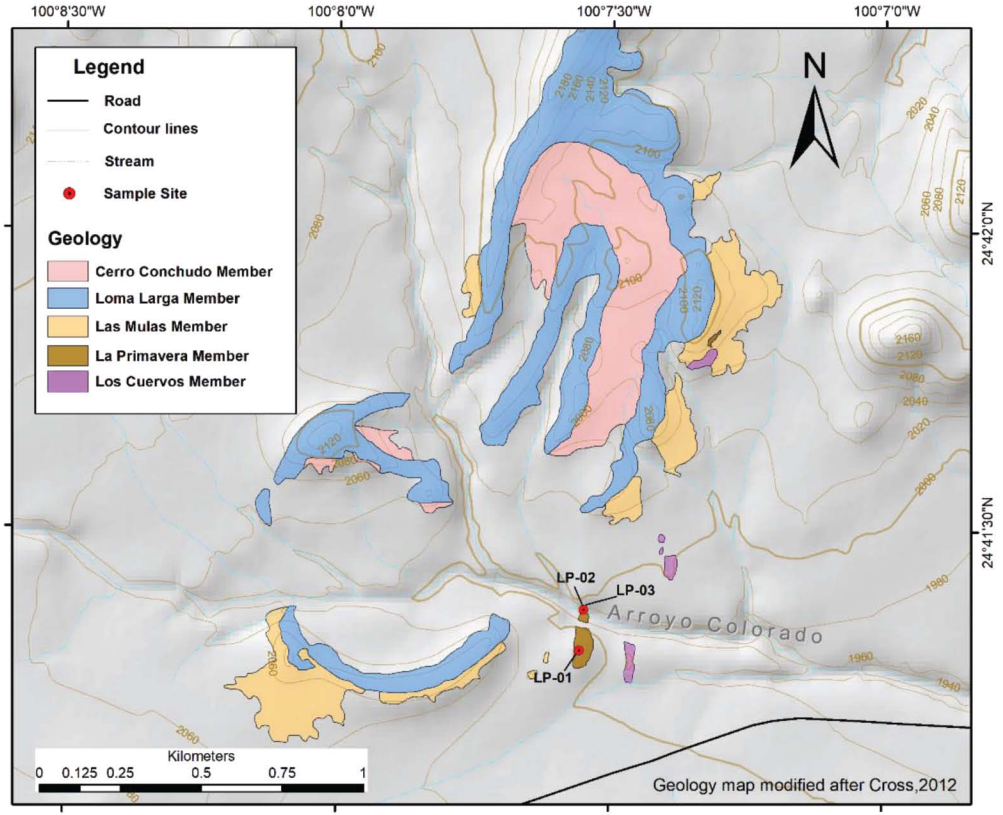
The principal outcrops are located southwest to Galeana near to La Primavera village.

Previously in this region the volcanic rocks were identified as a member of the Minas Viejas Formation by Kroeger and Stinnesbeck (2003).



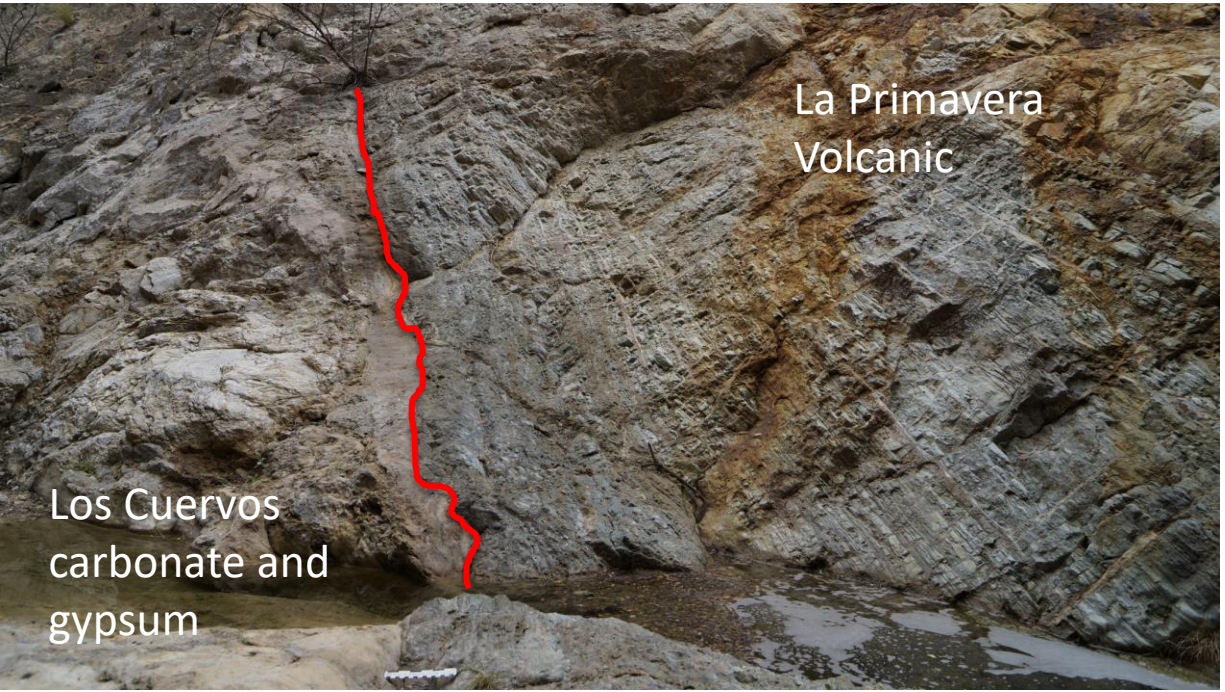
Cross (2012) made a detailed description of this succession and described eleven members, including La Primavera member which is the only one with a volcano-sedimentary genesis.





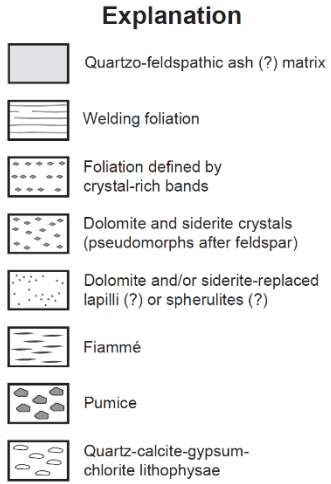
The samples from the La Primavera Member were collected at La Mesita and Arroyo Colorado outcrops where this member has the best display.

The Arroyo Colorado section has approximately 18 meters wide, with excellent exposition of the felsic tuff, which overlies the carbonate and gypsum, of Los Cuervos Member but the top of the sequence is not exposed.

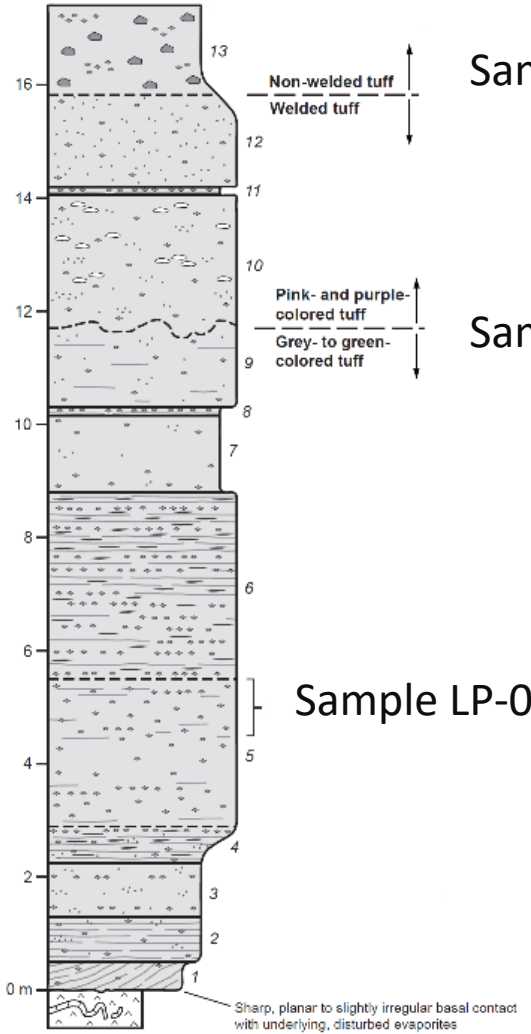


At the bottom of the sequence, is the contact with gypsum beds of the Los Cuervos Member. The contact is sharp, planar and apparently concordant.

Volcaniclastic material is interbedded with layers of gypsum which suggest a contemporary volcanism and sedimentary system.



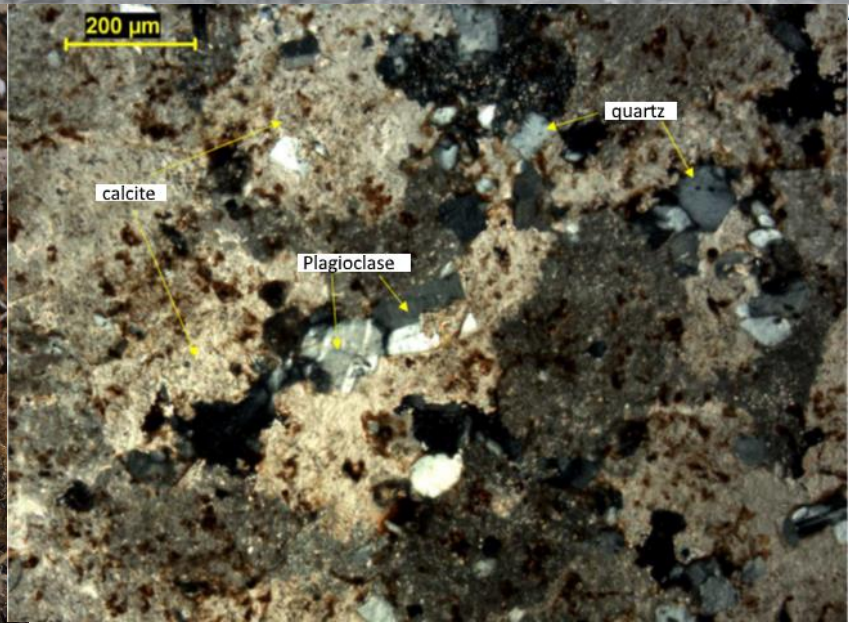
Section from Cross, 2012



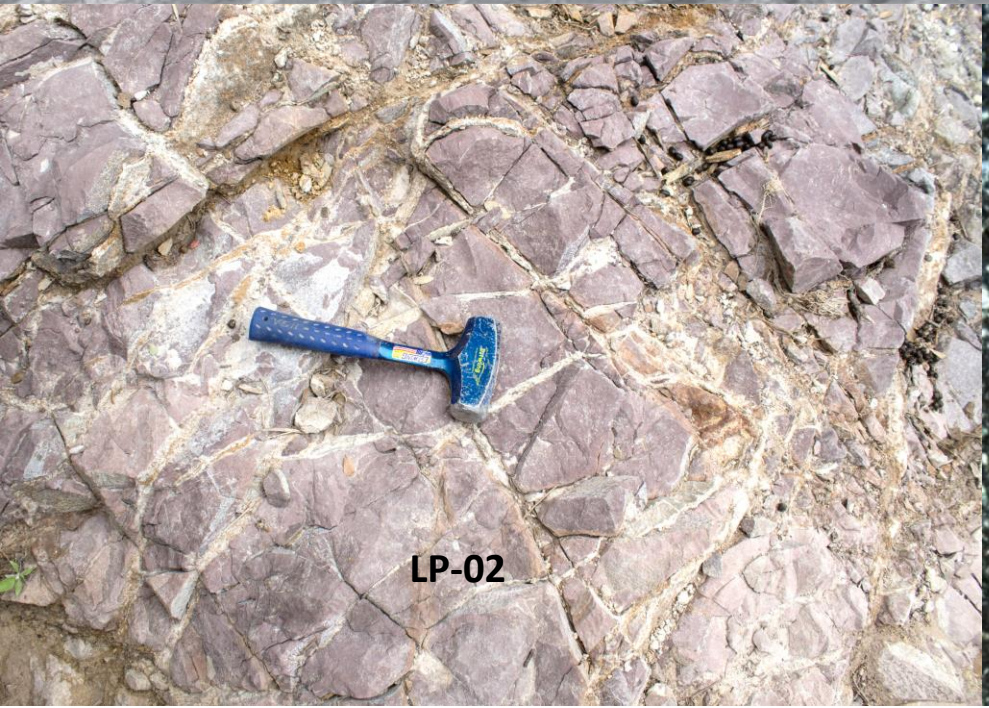
Sample LP-01

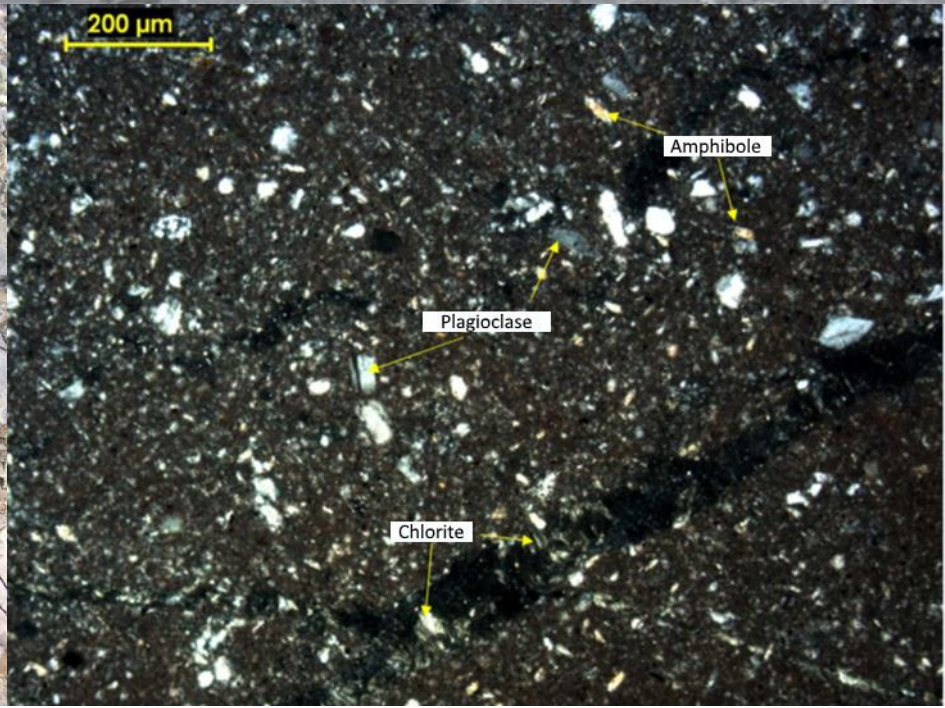
Sample LP-02

Sample LP-03

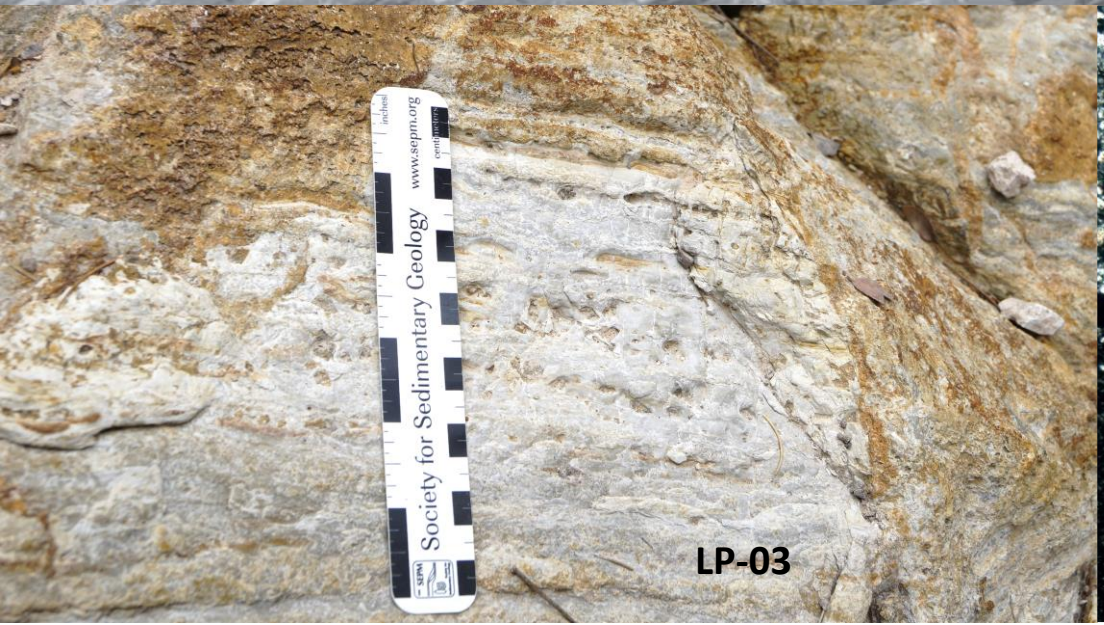


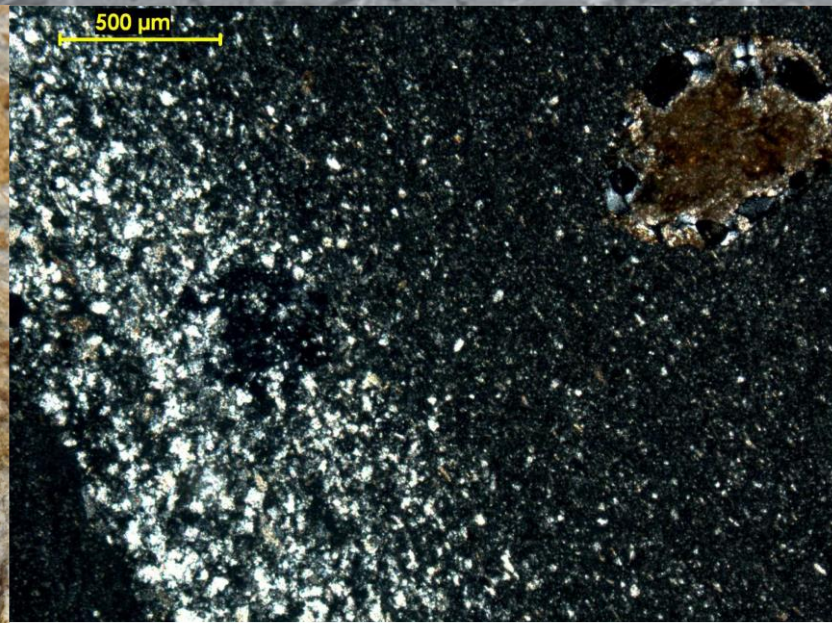
Intergrowth iron minerals are present in the sample LP-01 at the top of the sequence of the La Primavera Member as evidence of a diagenetic process. In thin section are visible a mixture between volcaniclastic and carbonate sources.





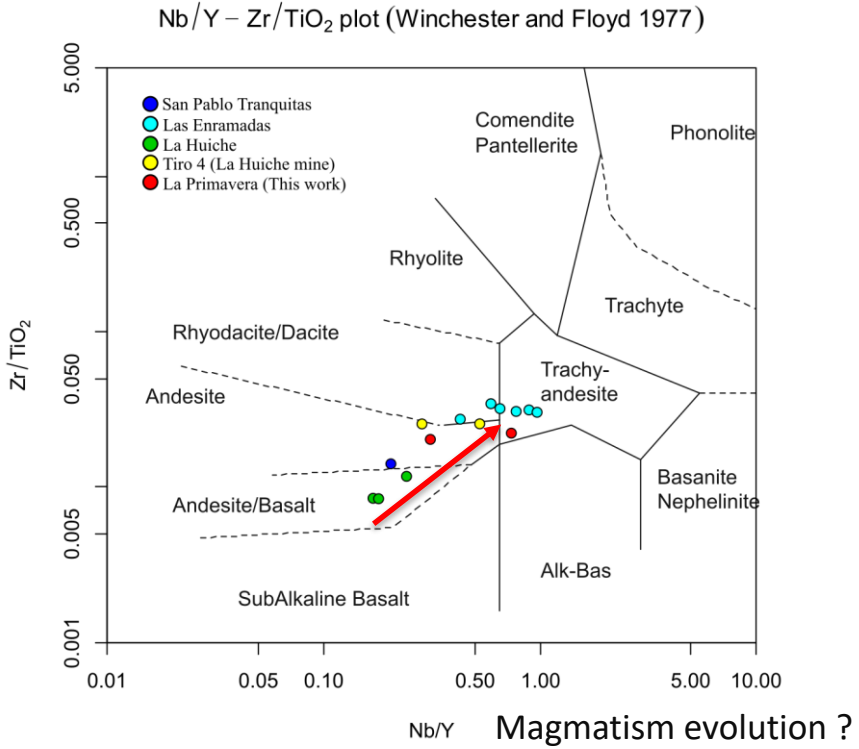
Massive red colored volcanic deposit with calcite and chlorite filled veins, this sample corresponds to a non-welded tuff.





Gray colored compact welded tuff, in thin section are observable layers of microcrystals and the replacement of phenocrysts by carbonate minerals.

Geochemical classification



Magmatism evolution ?

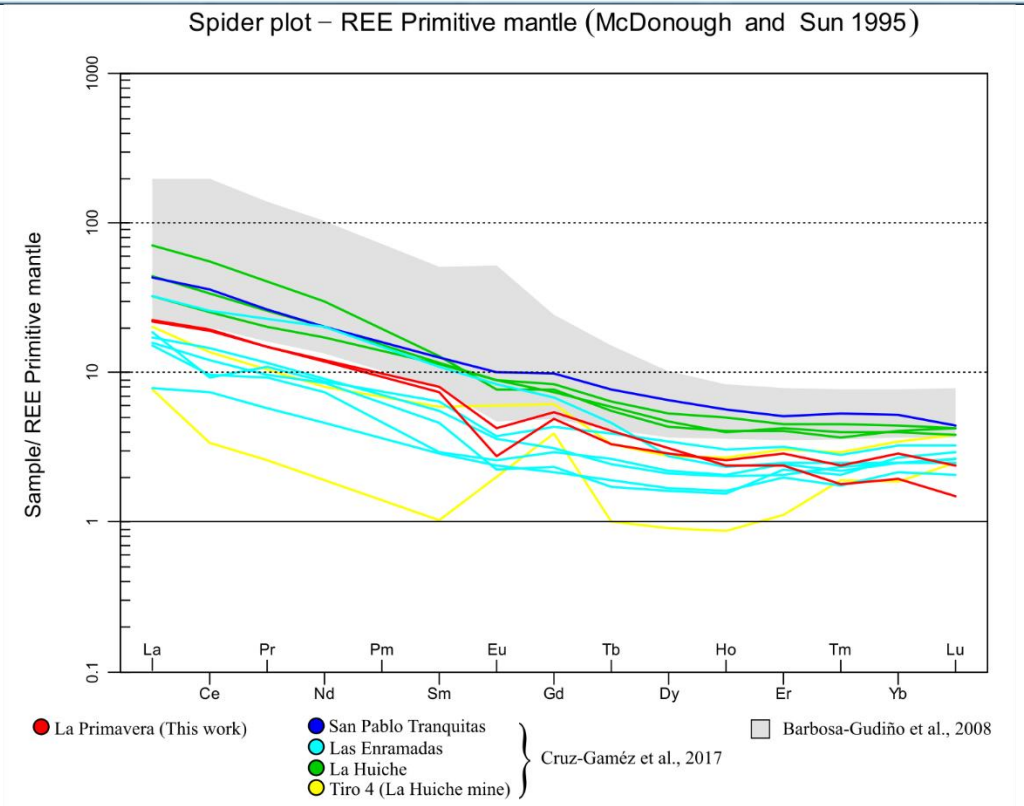
A classification based on immobile elements shows an andesitic-trachyandesitic composition.

La Primavera (This work) and previous data (Cruz-Gámez et al., 2017) from other volcanic rocks of Galeana (ages from 193 to 149 Ma).

La Huiche and San Pablo Tranquitas basic to intermediate dykes and sills.(Alamar F. Lower Jurassic)
Las Enramadas and Tiro 4 Dome structures with porphyritic texture. (Minas Viejas Fm. Upper Jurassic)

REE

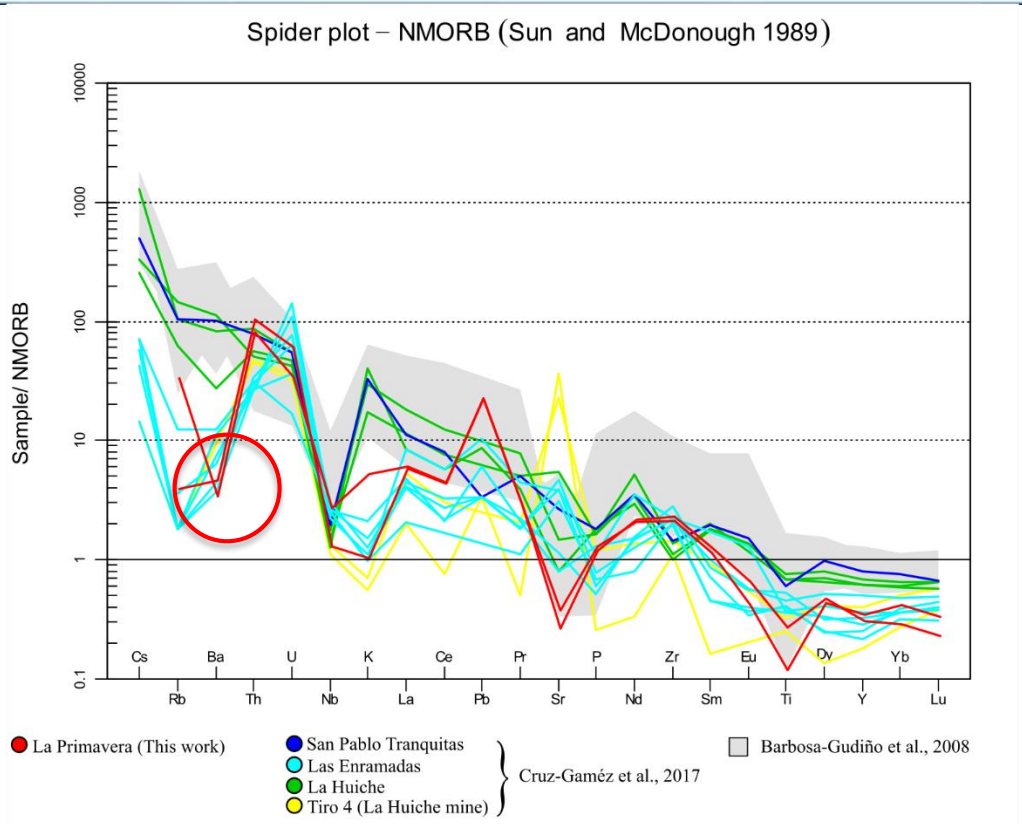
Rocks from La Primavera member exhibit an enrichment of light-REE, with light Eu anomaly and almost flat pattern for heavy-REE.

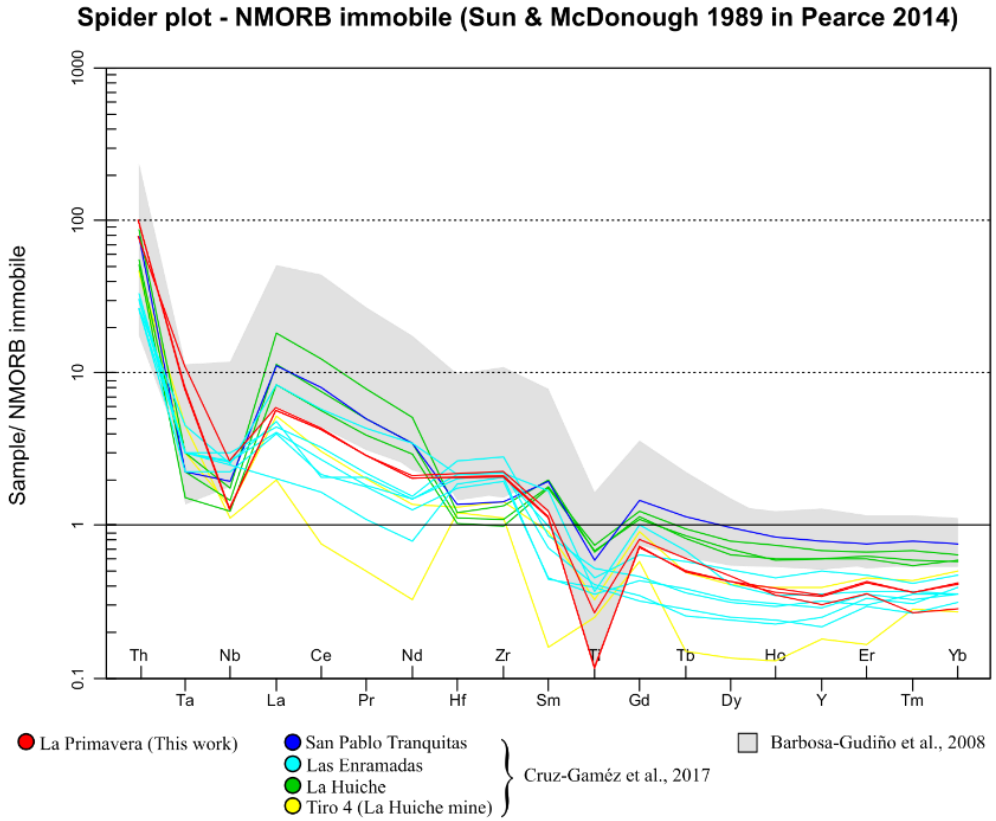


Trace elements

General enrichment in LILE and depletion of Nb, Sr and Ti.

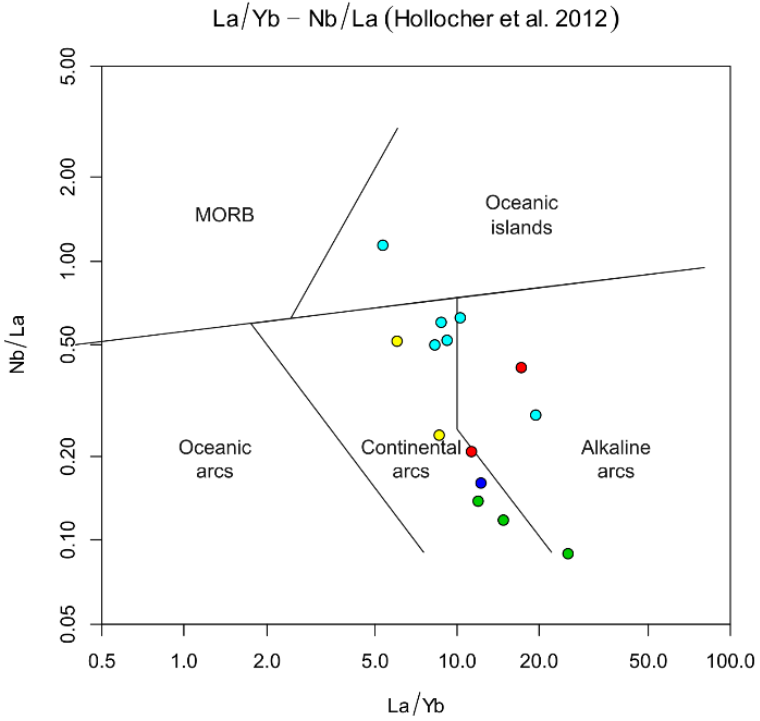
Depletion on Rb, Ba and K caused by alteration?

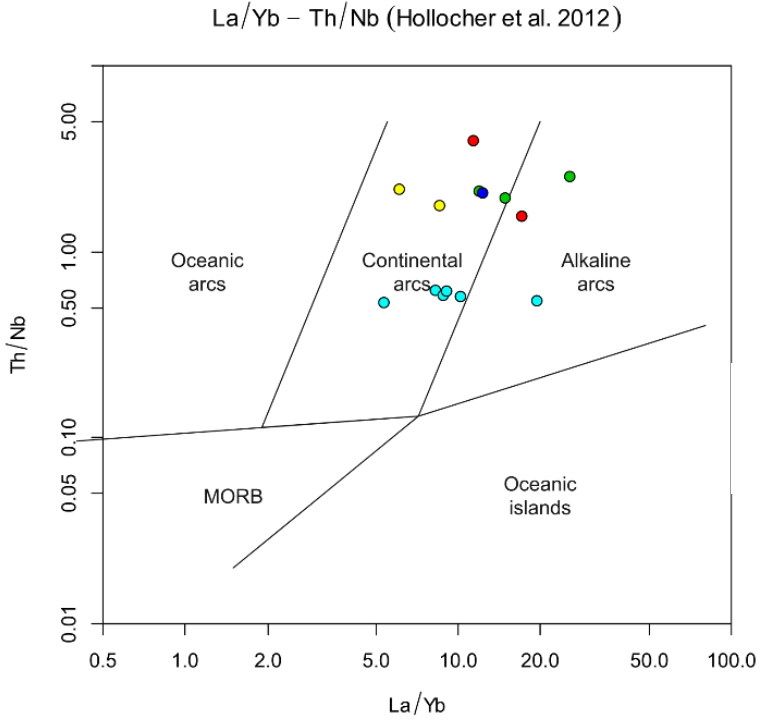




Comparison only with immobile elements the geochemical signature of La Primavera´s samples are closer to the regional magmatism of Pre-Oxfordian rocks in northeastern Mexico.

Geotectonic





- San Pablo Tranquitas
- Las Enramadas
- La Huiche
- Tiro 4 (La Huiche mine)
- La Primavera (This work)

Geochronology

151.15 Ma

153.85 Ma

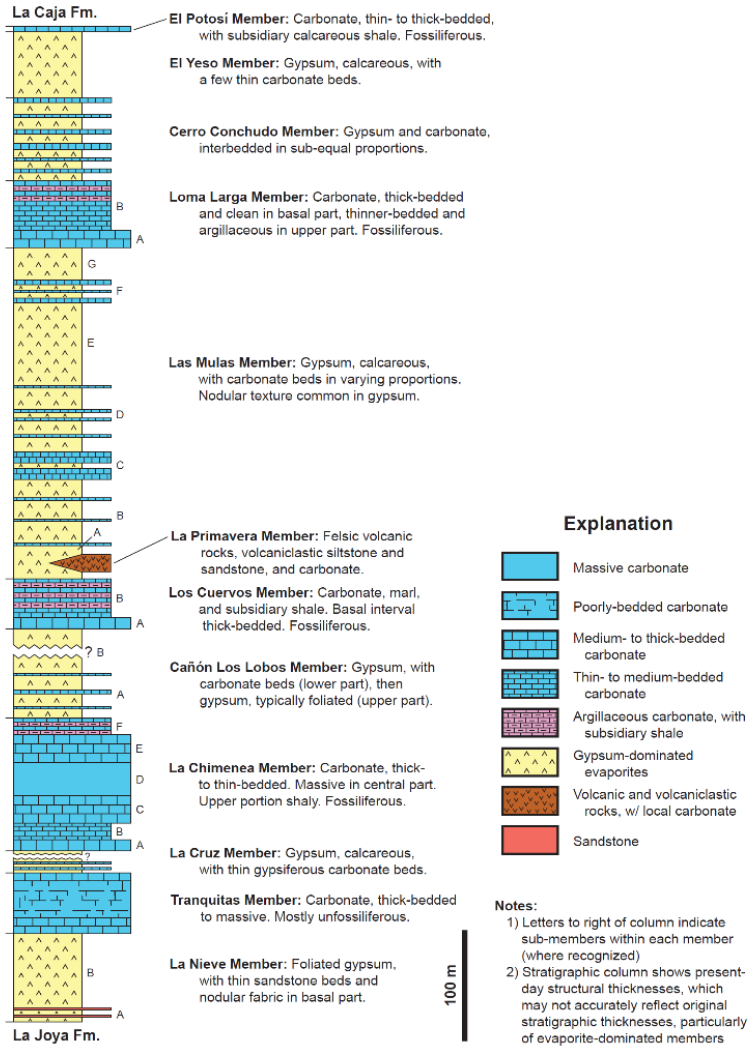
Callovian age for La Primavera member?

164.8 Ma
Cross, 2012

168.25-165.35 Ma

This age is concordant with our $^{87}Sr/^{86}Sr$ dating

169.30-169.75 Ma



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Strontium and Neodymium isotopes

The analysis for two samples were processed at LUGIS, Instituto de Geofísica, UNAM. The results show crustal crust isotopic ratios and Precambrian neodymium model ages.

Sample	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	1 sd*	1 SE(M)	n	Concentration (D.I.) ppm Rb	Concentration (D.I.) ppm Sr	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	1 sd*	1 SE(M)	n	εNd	1σ	Concentration (D.I.) ppm Sm	Concentration (D.I.) ppm Nd	Model Age (TDM) Ma Nd
LP-02	1.519	0.709123	30	4	59	16.14	30.75	0.118	0.512324	17	2	66	-6.13	0.33	6.39	32.68	1231
LP-03	0.104	0.707670	30	4	56	1.47	40.91	0.115	0.512339	13	2	67	-5.83	0.25	4.50	23.68	1167

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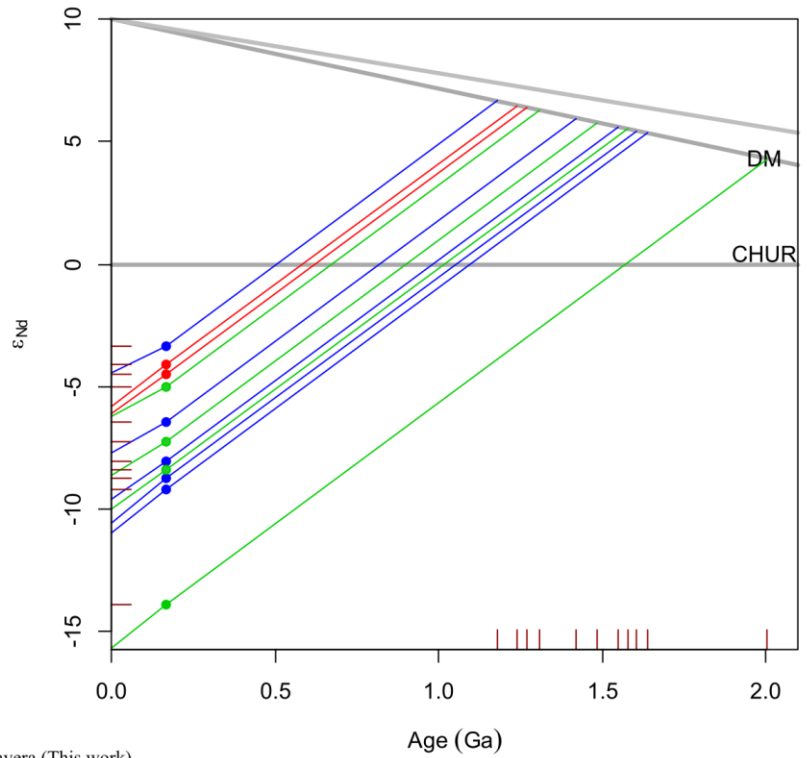
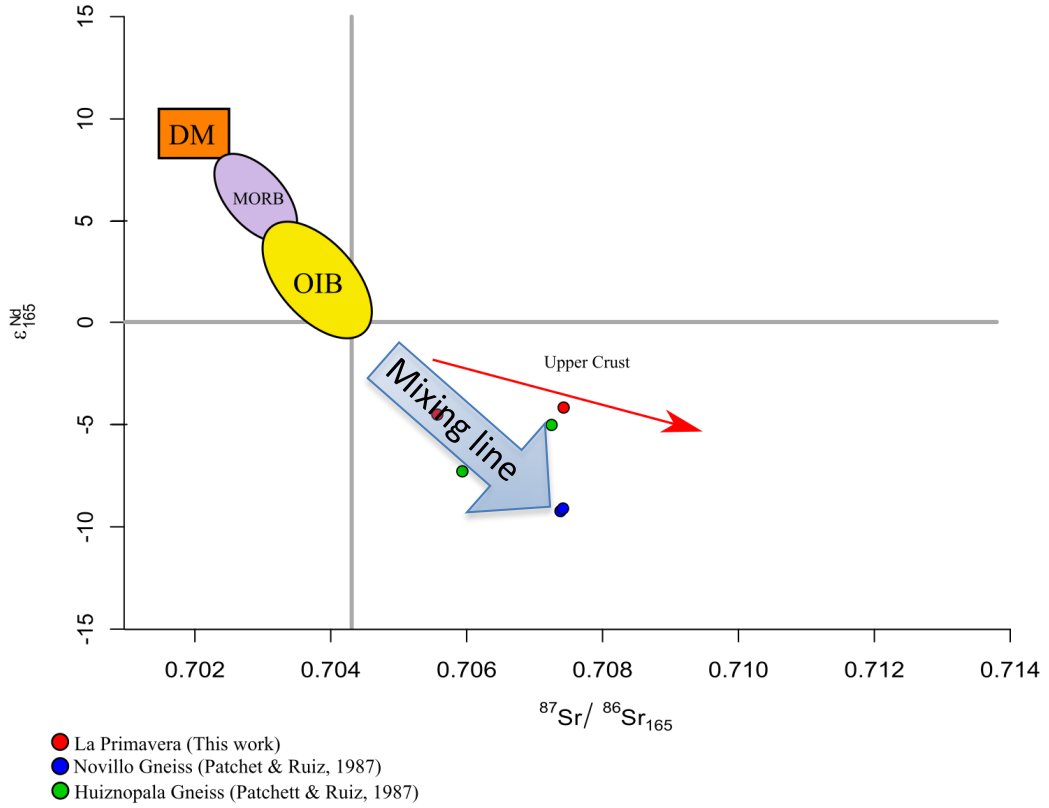
Neodymium model ages TDM

Model ages for analyzed samples reach 1.2 Ga, similar to the TDM ages reported for the basement rocks of El Novillo and Huiznopala Gneisess 1.3 to 1.7 Ga



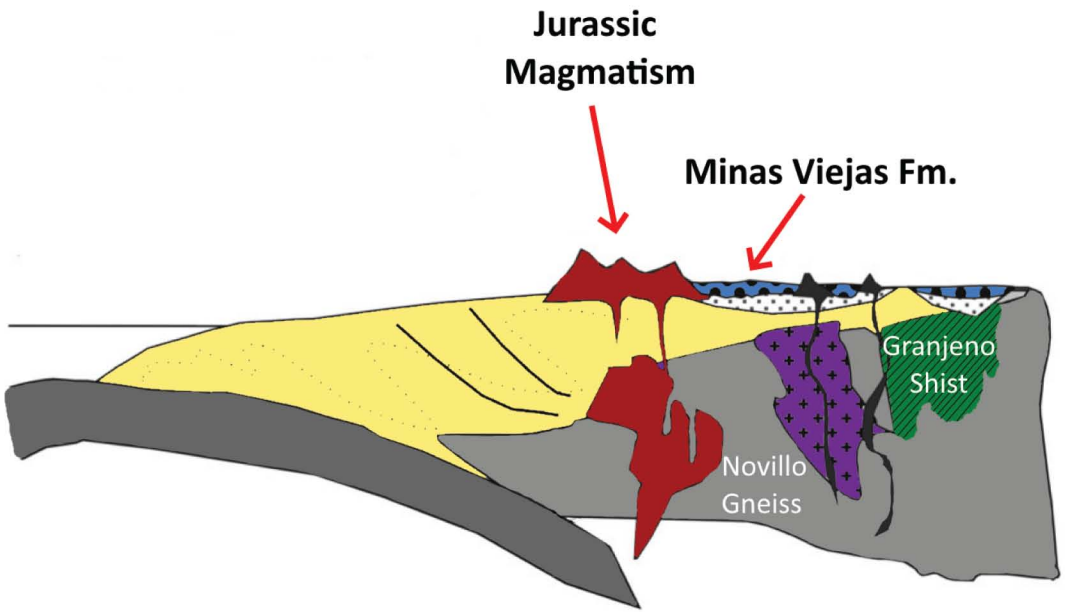
εNd_i vs. Sr_i



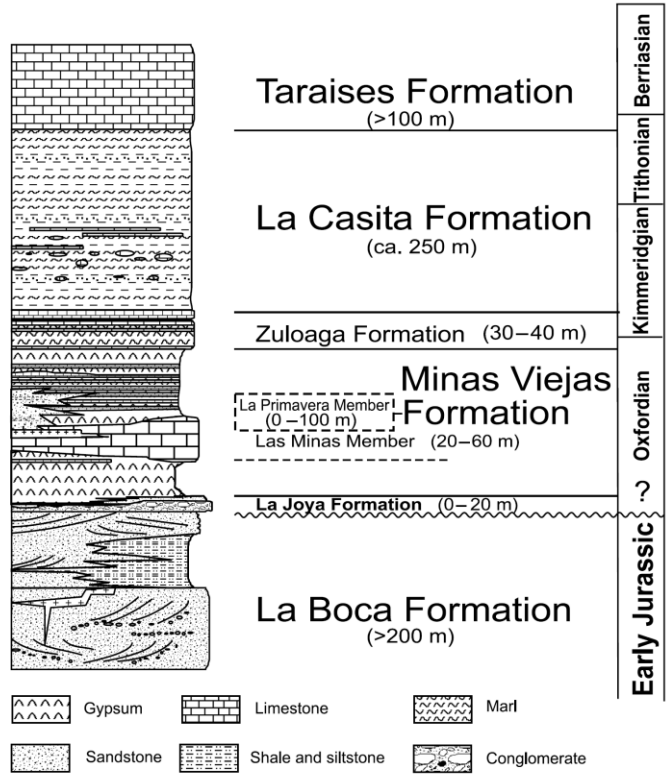
Discussion

The Magmatism of La Primavera Member has a Volcanic Arc geochemical signature.

Isotopic ratios of Nd and Sr display a high continental component with ancient Nd model ages from 1.1 to 1.2 Ga.



Modified from Barboza-Gudiño et al., 2008



Stratigraphy from Kroeger & Stinnesbeck, 2003

The Age considered in this work for La primavera and Minas Viejas Formation, are opposed to a previous Oxfordian determinations but these are consistent with some ages for the underlying La Joya Fm.

Author	Formation	Age Ma
Cross, 2012	Minas Viejas (La Primavera)	164.8 ± 3
Rubio-Cisneros & Lawton, 2011	La Joya	168 ± 17 (Weighted Mean Age)
Barbosa-Gudiño, 2012	La Joya	~170
Pérez-Casillas, 2018	La Joya	~166- 240

Conclusions

- Volcanic rocks from La Primavera Member exhibit a volcanic arc geochemical signature.
- The volcanic and volcaniclastic deposits are associated to the magmatic activity in the Galeana region which was develop from 193 Ma to 149 Ma.
- Isotopic evidence suggests the interaction of the magma source with Precambrian basement material (Novillo Gneiss).
- More geochronological and isotopic data is needed for a better comprehension of Late Jurassic Magmatism.

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