Analysis of geochemical controls on magnesium dissolution in the Chougafiya basin, Central Tunisia

Kayleigh C. Alme

Department of Geosciences, NDSU

Geol 428 Geochemistry

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Preview

- Location and Background
- Reference study
- Geochemical model
- Results
- Discussion
- Tritium (if time)

Location

Google Maps

Location

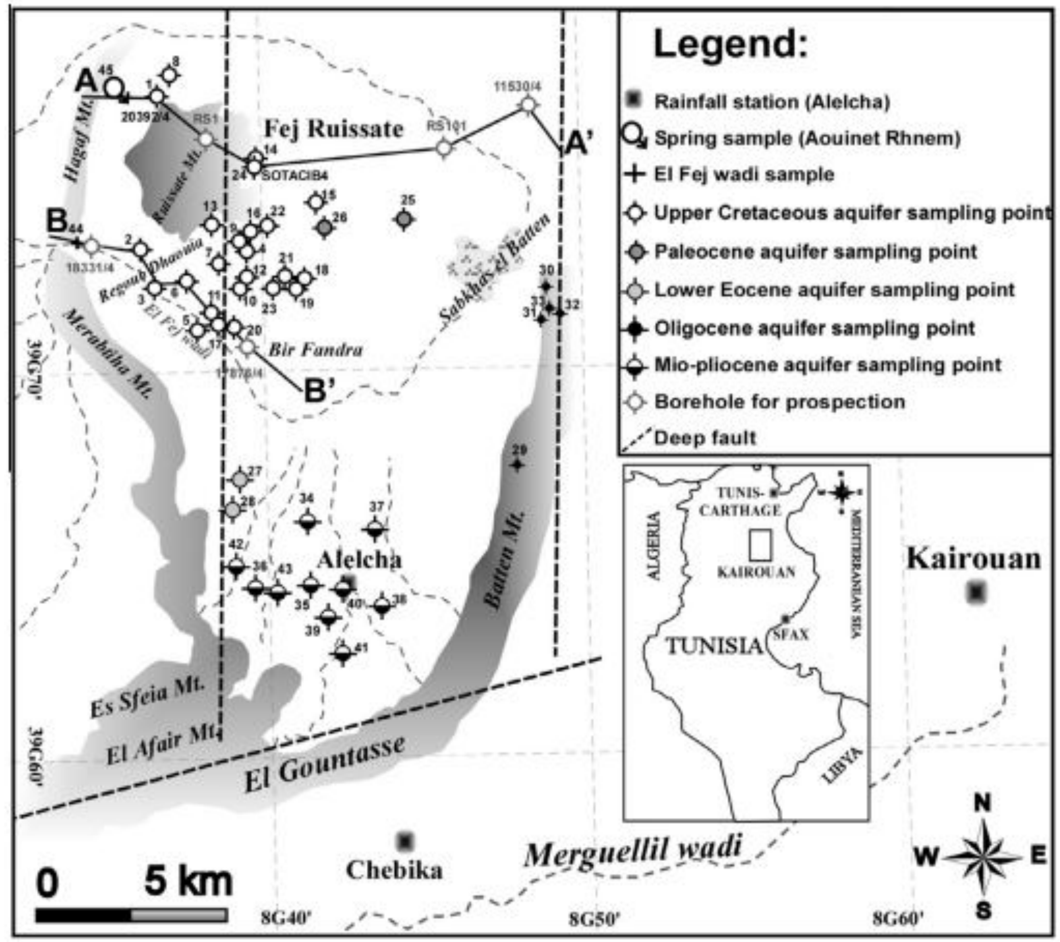

Fig. 1. Location of sampling sites within the Chougafiya basin.

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From Farid, et al (2015)

Background

- Endorheic basin
- Multiple aquifers within basin
- Discontinuous
- Mean annual precip < 350 mm
- Mean annual temp = 19.8˚C

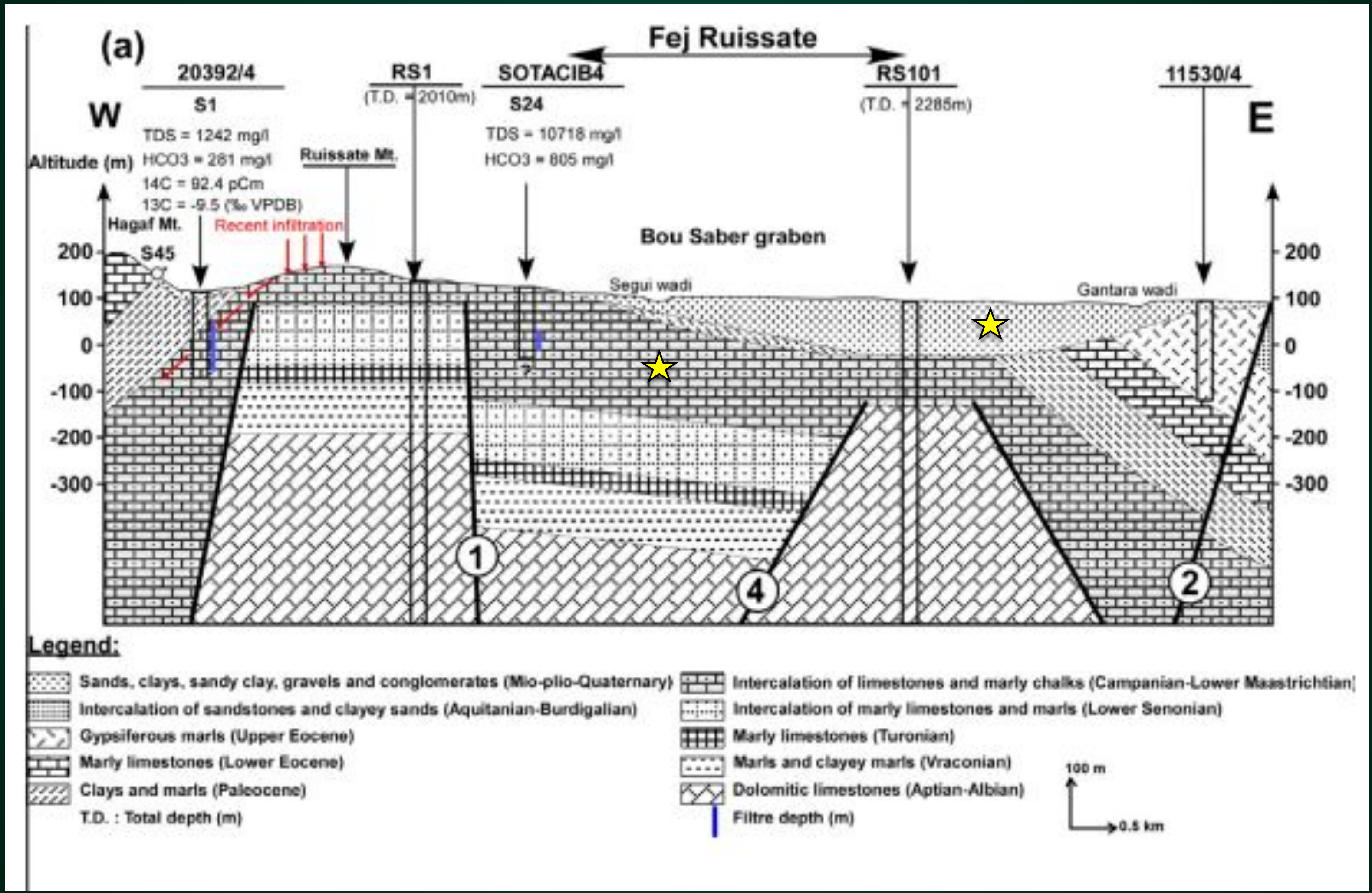
Age	Lithology	Formation	Stratigraphic column	Aquifers
Quaternary	Gravels, sands alluviums, clays			Permeable
Mio-pliocene	Sands and clays	SEGUI		Permeable
Miocene	Sandstones and marls	OUM DHOUIL		Semi-Permeable
Oligocene	sandstones and marls	FORTUNA		Semi-Permeable
Upper Eocene	Clays and marls	SOUAR		Impermeable
Lower Eocene	Limestones	METLAOUI		Permeable
Paleocene	Pebbles and marls	EL HARIA		Semi-Permeable
Maastrichtian-Campanian	Limestones	ABIOD		Permeable
Coniacian-Santonian	Clays and marly limestones	ALEG		Semi-Permeable
Aptian-Albian	Carbonates	SERDJ		Permeable
Hauterivian-Barremian	Clays dolomite	BOU HEDMA		Semi-Permeable
Valanginian-Hauterivian	Carbonates sandstones	MELLOUSSI BOU DINAR		Permeable

Exploited aquifer

Non-exploited aquifer

Fig. 3. Simplified lithostratigraphic column of the study area.

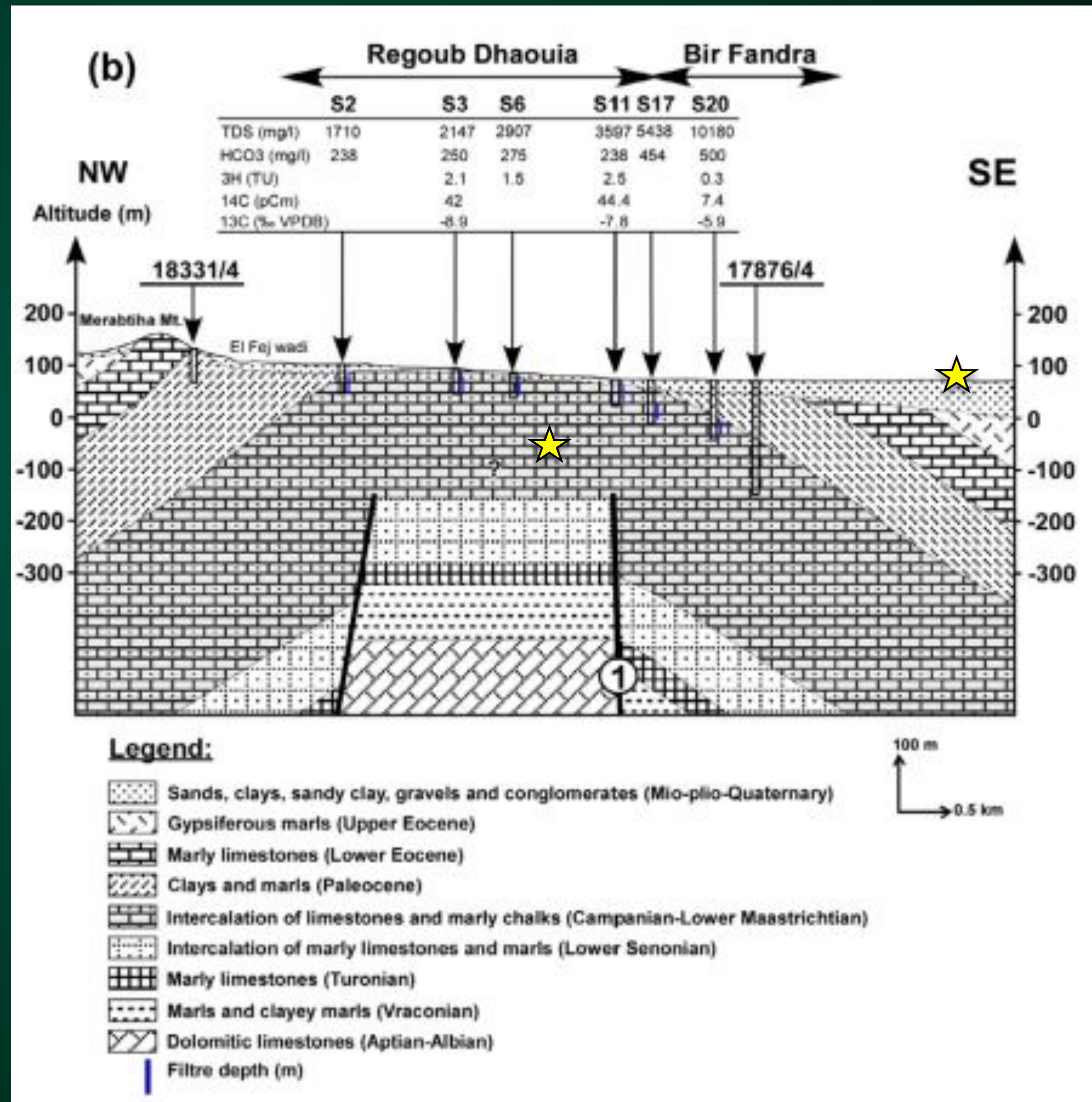
Geology



(a)
Fej Ruissate
20392/4
S1
RS1
(T.D. = 2010m)
SOTACIB4
S24
RS101
(T.D. = 2285m)
11530/4
W
E
TDS = 1242 mg/l
HCO3 = 281 mg/l
14C = 92.4 pCm
13C = -9.5 (‰ VPDB)
TDS = 10718 mg/l
HCO3 = 805 mg/l
Altitude (m)
Ruissate Mt.
Hagaf Mt.
S45
Recent infiltration
Bou Saber graben
Segui wadi
Gantara wadi
200
100
0
-100
-200
-300
1
4
2
Legend:
Sands, clays, sandy clay, gravels and conglomerates (Mio-plio-Quaternary)
Intercalation of sandstones and clayey sands (Aquitanian-Burdigalian)
Gypsiferous marls (Upper Eocene)
Marly limestones (Lower Eocene)
Clays and marls (Paleocene)
T.D. : Total depth (m)
Intercalation of limestones and marly chalks (Campanian-Lower Maastrichtian)
Intercalation of marly limestones and marls (Lower Senonian)
Marly limestones (Turonian)
Marls and clayey marls (Vraconian)
Dolomitic limestones (Aptian-Albian)
Filtre depth (m)
100 m
0.5 km

Geology

- Horst and Graben
- Different lithologies throughout basin
- Mio-Pliocene: sands, clays, gravels, and conglomerates
- Upper Cret.: limestones and marly chalks



Reference study

- Comprehensive study of groundwater within the Chougafiya Basin
- 45 water samples from the mentioned aquifers through boreholes
- Calculated SI's of halite, gypsum, anhydrite, dolomite, calcite, and aragonite for each sample using Phreecq
- Gave possible hypotheses for dissolution and mineralization

Reference Study

- Stated that high Mg^{2+} in Upper Cretaceous and Mio-Pliocene aquifers is evidence that the ion is increased in solution by incongruent dolomite dissolution

$$CaMg(CO_3)_2 \leftrightarrows CaCO_3 + Mg^{+2} + CO_3^{-2}$$

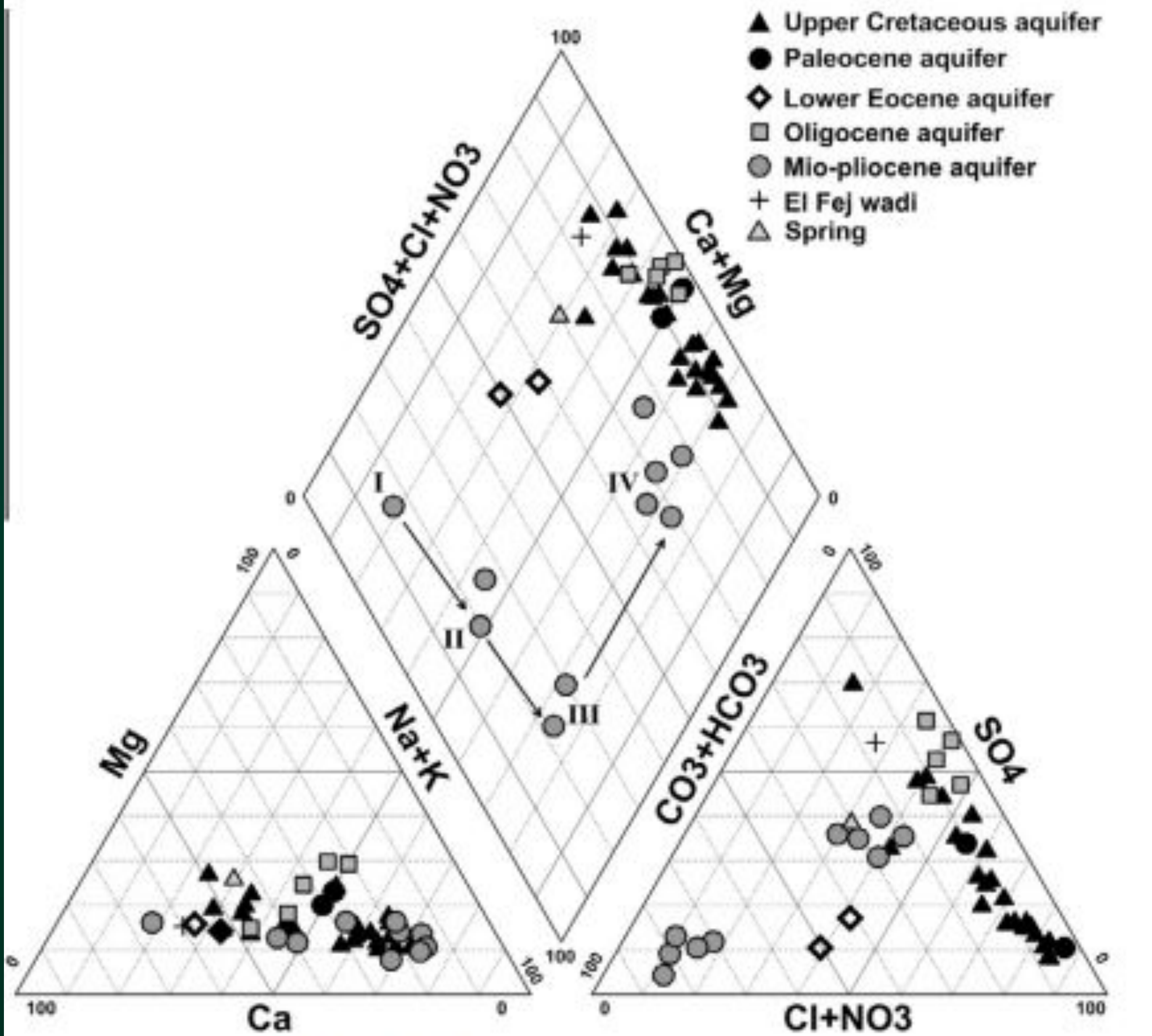


Fig. 7. Piper diagram of the analyzed water samples.

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No.	Sample type	Saturation indices					
		Halite	Gypsum	Anhydrite	Dolomite	Calcite	Aragonite
1	Upper Cretaceous aquifer	−6.0	−1.0	−1.3	−0.6	0.1	0.0
2	Upper Cretaceous aquifer	−6.2	−0.6	−0.8	0.1	0.4	0.3
3	Upper Cretaceous aquifer	−5.8	−0.5	−0.8	0.1	0.4	0.3
4	Upper Cretaceous aquifer	−5.2	−0.8	−1.0	−1.1	−0.1	−0.3
5	Upper Cretaceous aquifer	−5.5	−0.5	−0.7	0.1	0.4	0.3
6	Upper Cretaceous aquifer	−5.2	−0.4	−0.7	−0.4	0.2	0.1
7	Upper Cretaceous aquifer	−5.2	−0.4	−0.6	0.3	0.7	0.5
8	Upper Cretaceous aquifer	−4.8	−0.8	−1.0	0.6	0.7	0.5
9	Upper Cretaceous aquifer	−4.7	−1.0	−1.2	−0.2	0.2	0.0
10	Upper Cretaceous aquifer	−4.8	−0.6	−0.9	0.0	0.5	0.4
11	Upper Cretaceous aquifer	−5.1	−0.4	−0.6	−0.1	0.4	0.2
12	Upper Cretaceous aquifer	−4.7	−0.7	−0.9	−0.6	0.1	−0.1
13	Upper Cretaceous aquifer	−4.9	−0.4	−0.7	−0.3	0.3	0.1
14	Upper Cretaceous aquifer	−4.5	−0.8	−1.0	−0.2	0.2	0.1
15	Upper Cretaceous aquifer	−4.5	−0.7	−0.9	0.5	0.7	0.6
16	Upper Cretaceous aquifer	−4.5	−0.6	−0.8	0.0	0.4	0.3
17	Upper Cretaceous aquifer	−4.4	−0.6	−0.8	1.5	1.0	0.8
18	Upper Cretaceous aquifer	−4.2	−0.6	−0.8	0.1	0.4	0.2
19	Upper Cretaceous aquifer	−4.0	−0.6	−0.9	0.0	0.3	0.1
20	Upper Cretaceous aquifer	−3.7	−0.5	−0.7	0.0	0.2	0.1
21	Upper Cretaceous aquifer	−3.8	−0.6	−0.8	−0.7	0.1	−0.1
22	Upper Cretaceous aquifer	−3.7	−0.5	−0.7	−0.1	0.2	0.1
23	Upper Cretaceous aquifer	−3.8	−0.6	−0.8	0.1	0.4	0.3
24	Upper Cretaceous aquifer	−3.6	−0.6	−0.9	−0.4	0.1	0.0
34	Mio-pliocene aquifer	−5.8	−1.0	−1.3	−0.3	0.2	0.0
35	Mio-pliocene aquifer	−6.1	−1.5	−1.7	−0.2	0.2	0.0
36	Mio-pliocene aquifer	−5.8	−1.4	−1.6	0.0	0.3	0.1
37	Mio-pliocene aquifer	−7.7	−2.5	−2.7	−0.9	0.1	−0.1
38	Mio-pliocene aquifer	−7.1	−2.6	−2.8	−0.6	−0.1	−0.2
39	Mio-pliocene aquifer	−7.4	−2.5	−2.7	−0.6	0.0	−0.2
40	Mio-pliocene aquifer	−8.4	−2.8	−3.0	−0.8	0.1	0.0
41	Mio-pliocene aquifer	−7.8	−2.5	−2.7	−0.7	0.1	0.0
42	Mio-pliocene aquifer	−5.6	−1.1	−1.3	−0.5	0.2	0.0
43	Mio-pliocene aquifer	−5.8	−1.4	−1.6	−0.2	0.2	0.1

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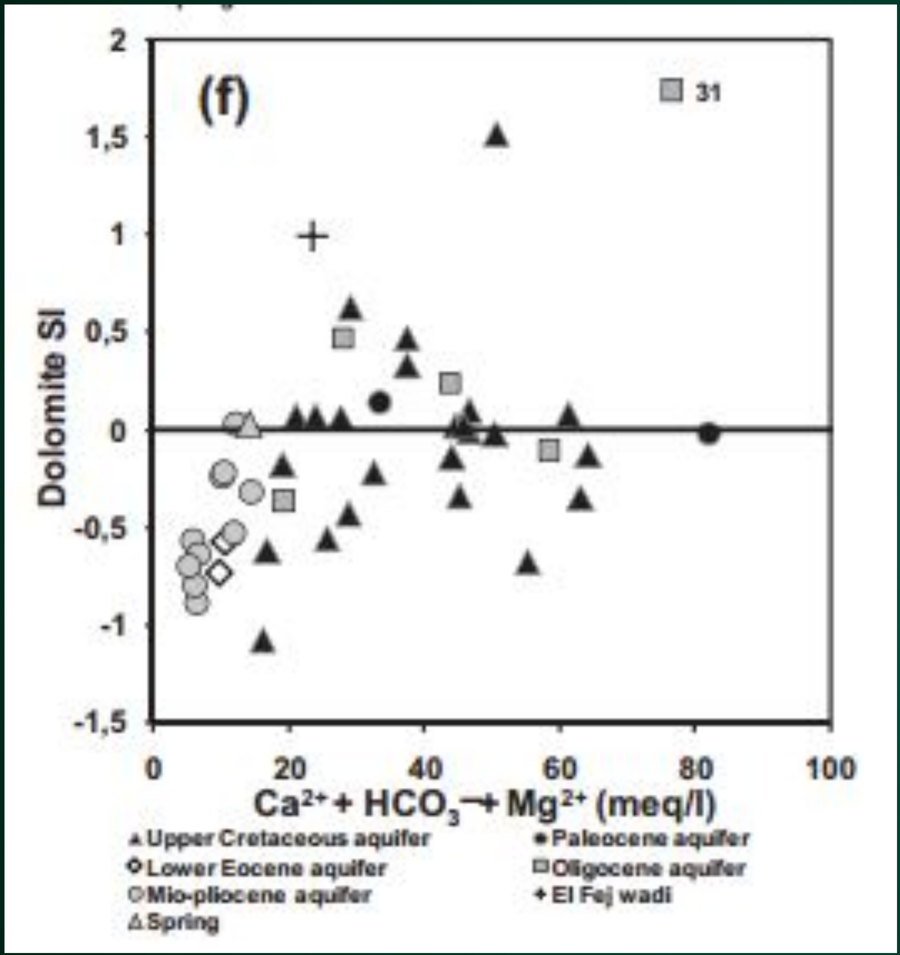

- Authors state that "such a process is obviously justified by the graph" (left)
- Notice undersaturaion of dolomite, with relatively low levels of Mg^{2+}

Geochemical Model

- Is Mg^{2+} more prevalent due to dissolution of dolomite?
- Model: Equilibrium phase
- Input water data as solution
- Input dolomite with SI=0
- Mg should increase as more dolomite dissociates

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Results: Mio-Pliocene Aquifer

Aquifer	Number	Mg (Initial) (ppm)	Mg (final) (ppm)	Difference
Mio-pliocene	1	0.001714	0.001955	0.000241
Mio-pliocene	2	0.001005	0.0009673	-3.77E-05
Mio-pliocene	3	0.001581	2.984912423	2.983331423
Mio-pliocene	4	0.0002757	0.0002992	0.0000235
Mio-pliocene	5	0.0004074	0.0004081	7E-07
Mio-pliocene	6	0.0003292	0.0003378	8.6E-06
Mio-pliocene	7	0.0002798	0.0002891	9.3E-06
Mio-pliocene	8	0.0002839	0.000288	4.1E-06
Mio-pliocene	9	0.0008568	0.0008439	-1.29E-05
Mio-pliocene	10	0.0009102	0.0008761	-3.41E-05

Results: Upper Cret. Aquifer*

Aquifer	Number	Mg (Initial)	Mg (final)	Difference
Up. Cret	1	0.001857	0.001875	0.000018
Up. Cret	2	0.00293	0.002839	-9.1E-05
Up. Cret	3	0.004204	0.004086	-0.000118
Up. Cret	4	0.002102	0.002148	4.6E-05
Up. Cret	5	0.002965	0.002861	-0.000104
Up. Cret	6	0.003366	0.00332	-0.000046
Up. Cret	7	0.003449	0.003223	-0.000226
Up. Cret	9	0.003099	0.003009	-9E-05
Up. Cret	10	0.00421	0.003951	-0.000259
Up. Cret	11	0.005448	0.005358	-9E-05
Up. Cret	12	0.003083	0.00306	-0.000023
Up. Cret	13	0.005491	0.005402	-8.9E-05
Up. Cret	15	0.003845	0.003456	-0.000389
Up. Cret	16	0.136	0.05926	-0.07674
Up. Cret	20	0.0155	0.01517	-0.00033
Up. Cret	21	0.007468	0.007571	0.000103

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*Not all water samples used. Only the ones with a given temperature.

Discussion

- 7/10 Mio-Pliocene samples increased in Mg^{2+}
- 3/16 Up. Cret. Increased in Mg^{2+}
- Is dissolution of dolomite really the controlling mechanism of the release of Mg^{2+}?

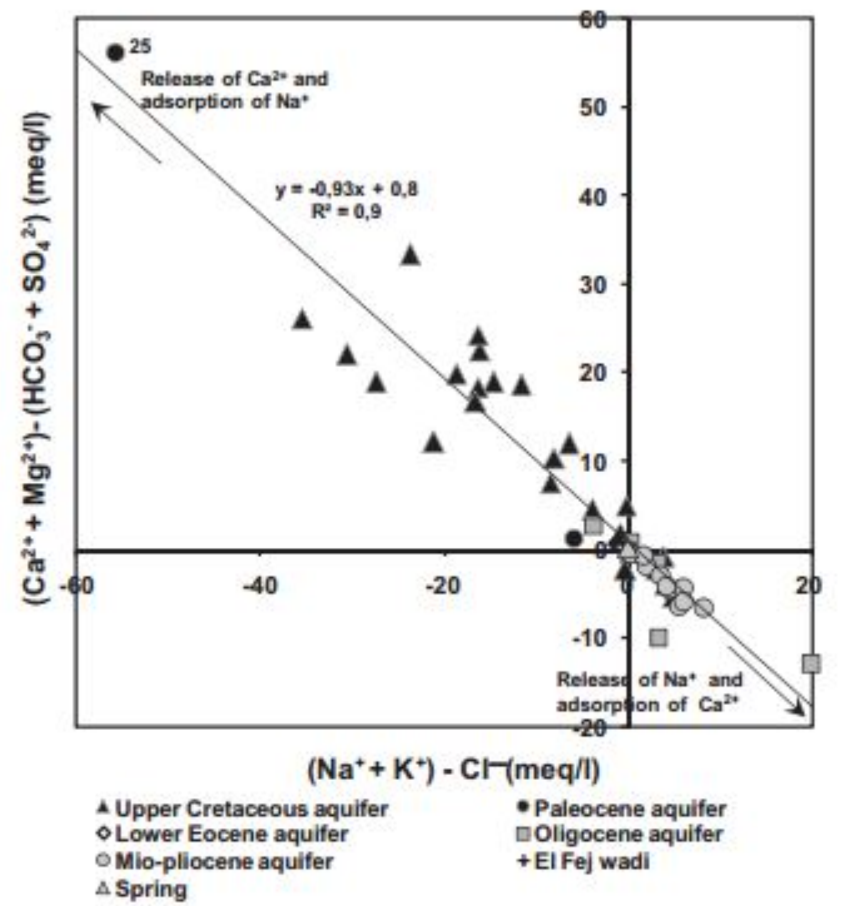

Fig. 9. [(Ca + Mg) – (SO₄ + HCO₃)] vs. [(Na + K) – Cl] relationship of the analyzed water samples.

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Discussion

- All waters in basin participate in exchange of Na^+, Ca^{2+}, K^+, Mg^{2+} ions
- Exchange in clays
- More reasonable for the Upper Cretaceous aquifer
- Mio-Pliocene?

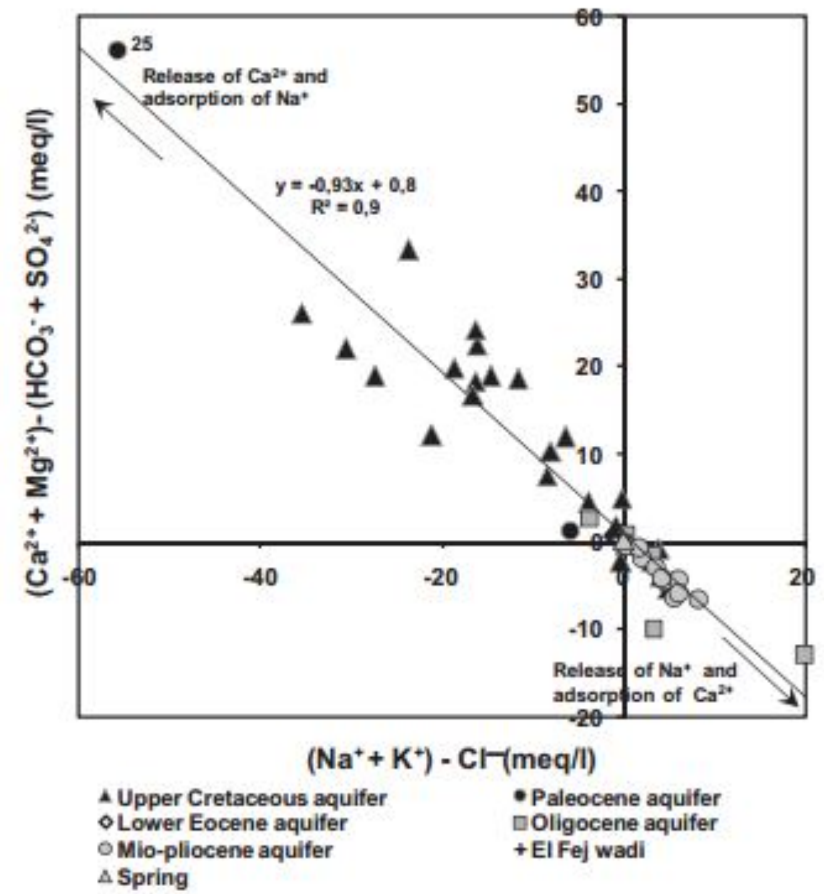

Fig. 9. [(Ca + Mg) − (SO_4 + HCO_3)] vs. [(Na + K) − Cl] relationship of the analyzed water samples.

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Discussion

- Upper Cretaceous Aquifer likely gains Mg^{2+} from cation exchange
- Mio-Pliocene Aquifer likely gains Mg^{2+} from dissolution of dolomite
- One problem..

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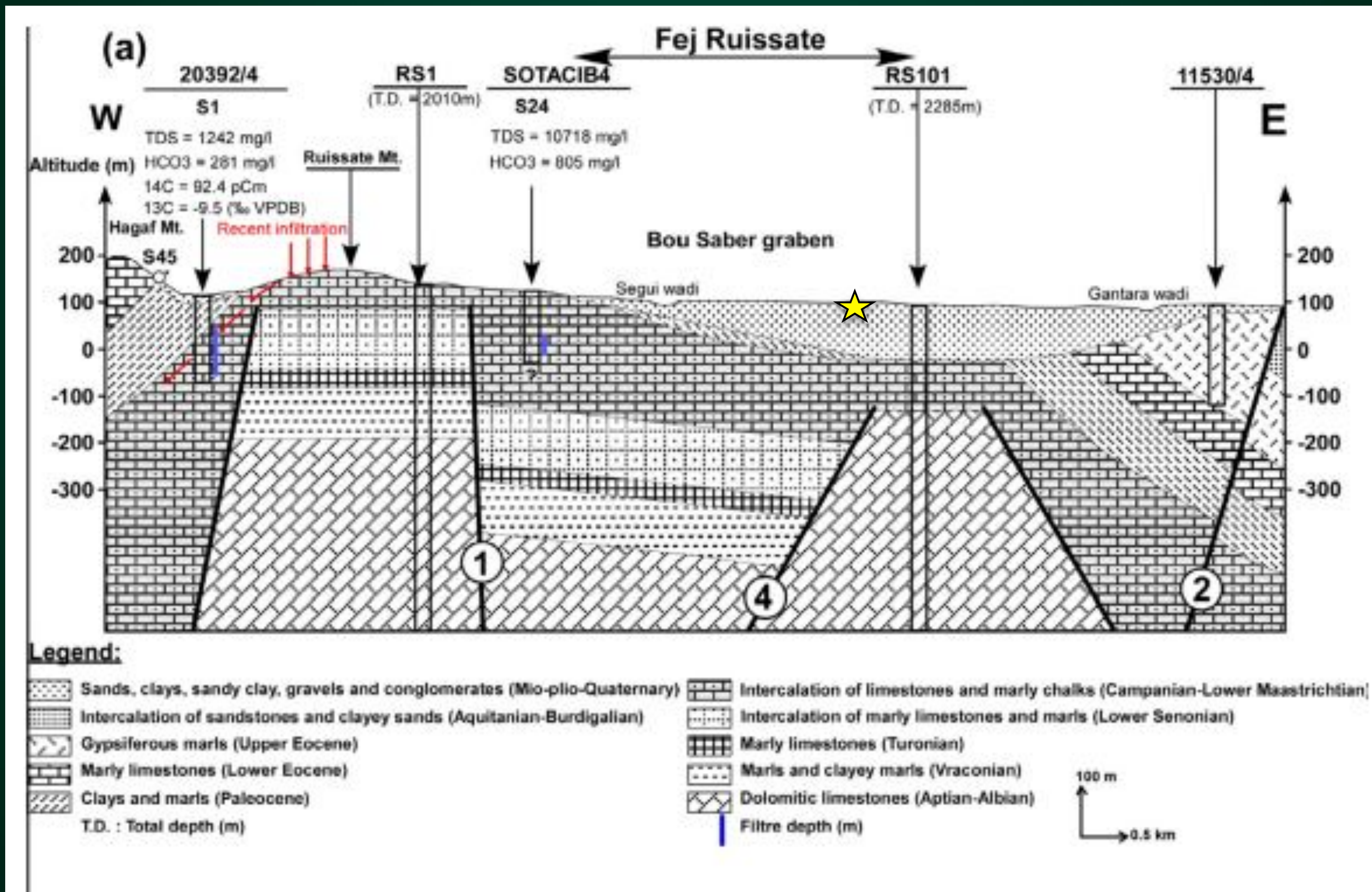
Discussion



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Marly limestones (Turonian)
Marls and clayey marls (Vraconian)
Dolomitic limestones (Aptian-Albian)
Filtre depth (m)
100 m
0.5 km

Discussion

- Local hydraulic connection
- Both rock layers are permeable
- Water could flow between the beds

Age	Lithology	Formation	Stratigraphic column	Aquifers
Quaternary	Gravels, sands alluviums, clays			Permeable
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Miocene	Sandstones and marls	OUM DHOUIL		Semi-Permeable
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Coniacian-Santonian	Clays and marly limestones	ALEG		Semi-Permeable
Aptian-Albian	Carbonates	SERDJ		Permeable
Hauterivian-Barremian	Clays dolomite	BOU HEDMA		Semi-Permeable
Valanginian-Hauterivian	Carbonates sandstones	MELLOUSSI BOU DINAR		Permeable

Exploited aquifer

Non-exploited aquifer

Fig. 3. Simplified lithostratigraphic column of the study area.

Significance

- Upper Cretaceous is far more briny
- Mio-Pliocene water is used for domestic purposes, farming, ranching, drinking
- Since 1980's-intensive over pumping
- A hydraulic connection between the two aquifers could impact the viability of the aquifer

Tritium

- ^3H
- Reliable tracer of modern waters (1950's to present)
- Most of tritium reached groundwaters during thermonuclear bomb testing
- $^3H < 1$ TU = pre-1952 age
- $^3H > 1$ = very recent
- Upper Cret = 0.3-2.6 TU
- Mio-Pliocene = 0-1.7 TU

References

- Farid, I., Zouari, K., Rigane, A., and Beji, R., 2015. Origin of the groundwater salinity and geochemical processes in detrital and carbonate aquifers: Case of Chougafiya basin (Central Tunisia). Journal of Hydrology. 530, p. 508-532.

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