Hydrogen embrittlement and piezonuclear reactions in electrolysis experiments

A. Carpinteri, O. Borla, A. Goi, A. Manuello, D. Veneziano

Department of Structural, Geotechnical and Building Engineering
Politecnico di Torino, Italy

ACKNOWLEDGEMENTS

G. Lacidogna, for his extensive collaboration

R. Sandrone for his contribution in geological issues

A. Chiodoni and S. Guastella for their contribution in micro-chemical analysis

NEUTRON EMISSION FROM FRACTURE AND EARTHQUAKES

NEUTRON EMISSION FROM EARTHQUAKES

- Sobolev, G.A., Shestopalov, I.P., Kharin, E.P. “**Implications of Solar Flares for the Seismic Activity of the Earth**”. Izvestiya, *Phys. Solid Earth* **34**: 603-607 (1998).
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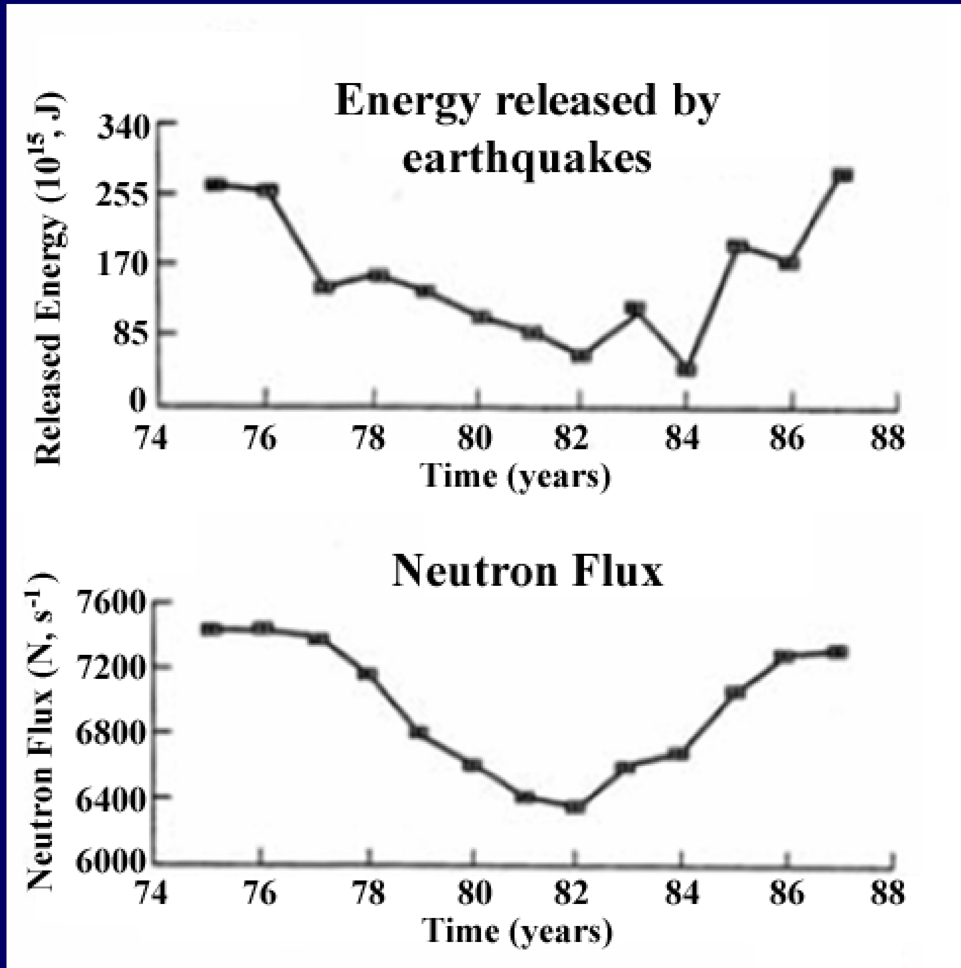
- Sigaeva, E., Nechaev, O., Panasyuk, M., Bruns, A., Vladimirsky, B. and Kuzmin Yu., “**Thermal neutrons’ observations before the Sumatra earthquake**”, *Geophysical Research Abstracts*, **8**: 00435 (2006).

(Continued)

As reported in the literature, an average **thermal neutron flux** up to 10^0 cm^{-2} s^{-1} **(10^3 times the background level)** was detected in correspondence to earthquakes with a magnitude of the 4th degree in Richter Scale (Volodichev N.N., et al. (1999)).

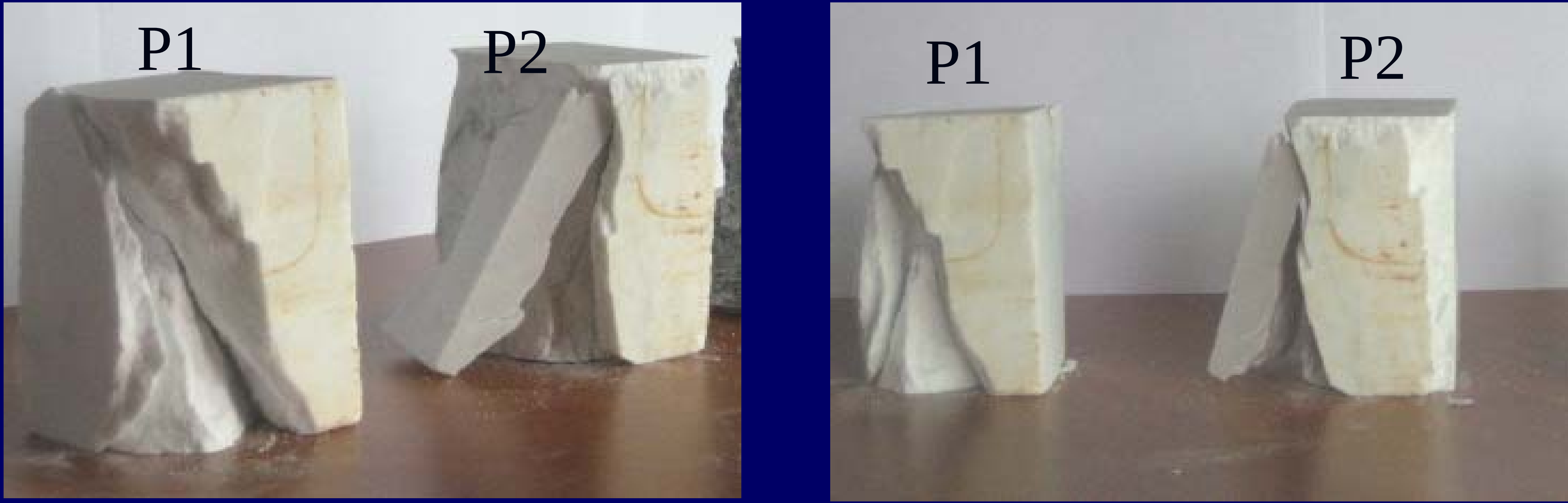


Global seismic activity and neutron flux measurements in the period 1974-1988. **Laboratory of Geophysical Precursors**, Oblast' Murmansk, Apatity, **Kola Peninsula**, Russia (Sobolev et al. 1998).

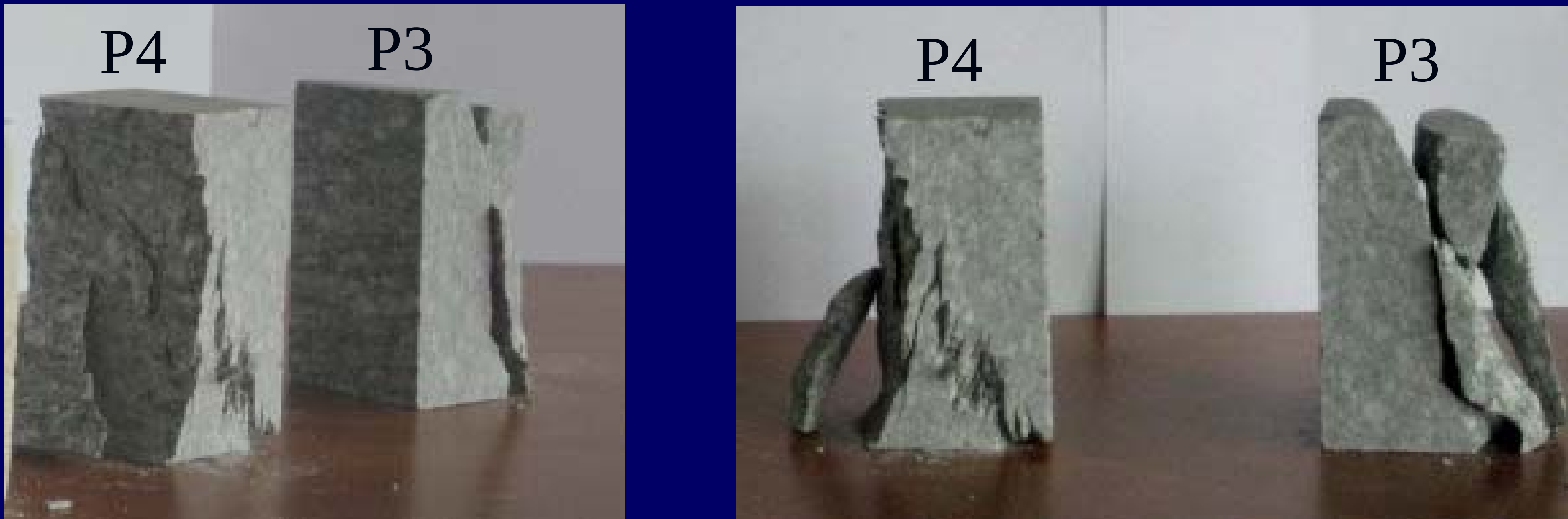
NEUTRON EMISSION FROM ROCK SPECIMENS

During a preliminary experimental analysis four rock specimens were used:

- two made of **Carrara marble**, specimens P1 and P2;
- two made of **Luserna granite**, specimens P3 and P4;
- all of them measuring **6x6x10 cm^3**.

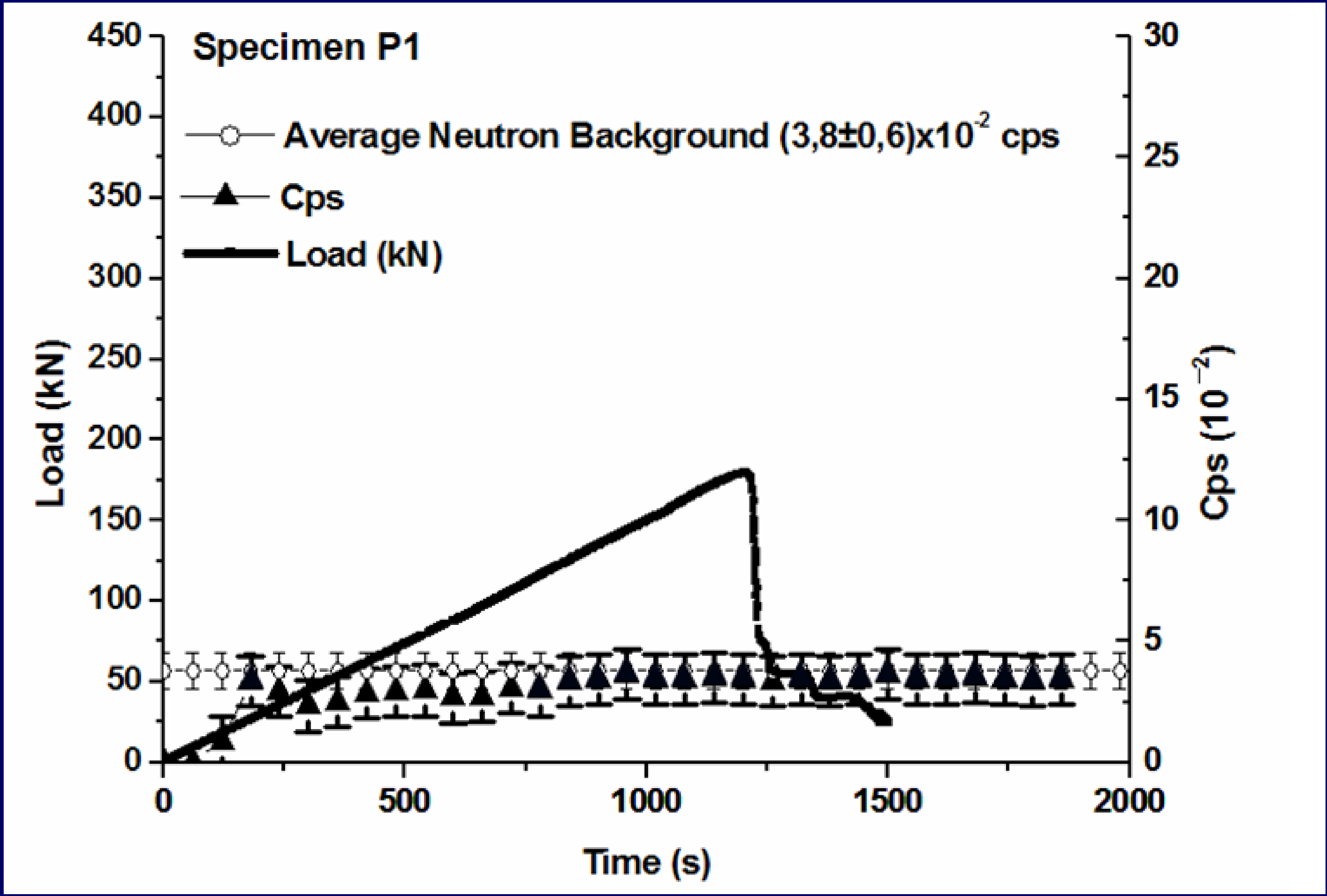


Specimens P1 and P2 in Carrara marble following compression failure.



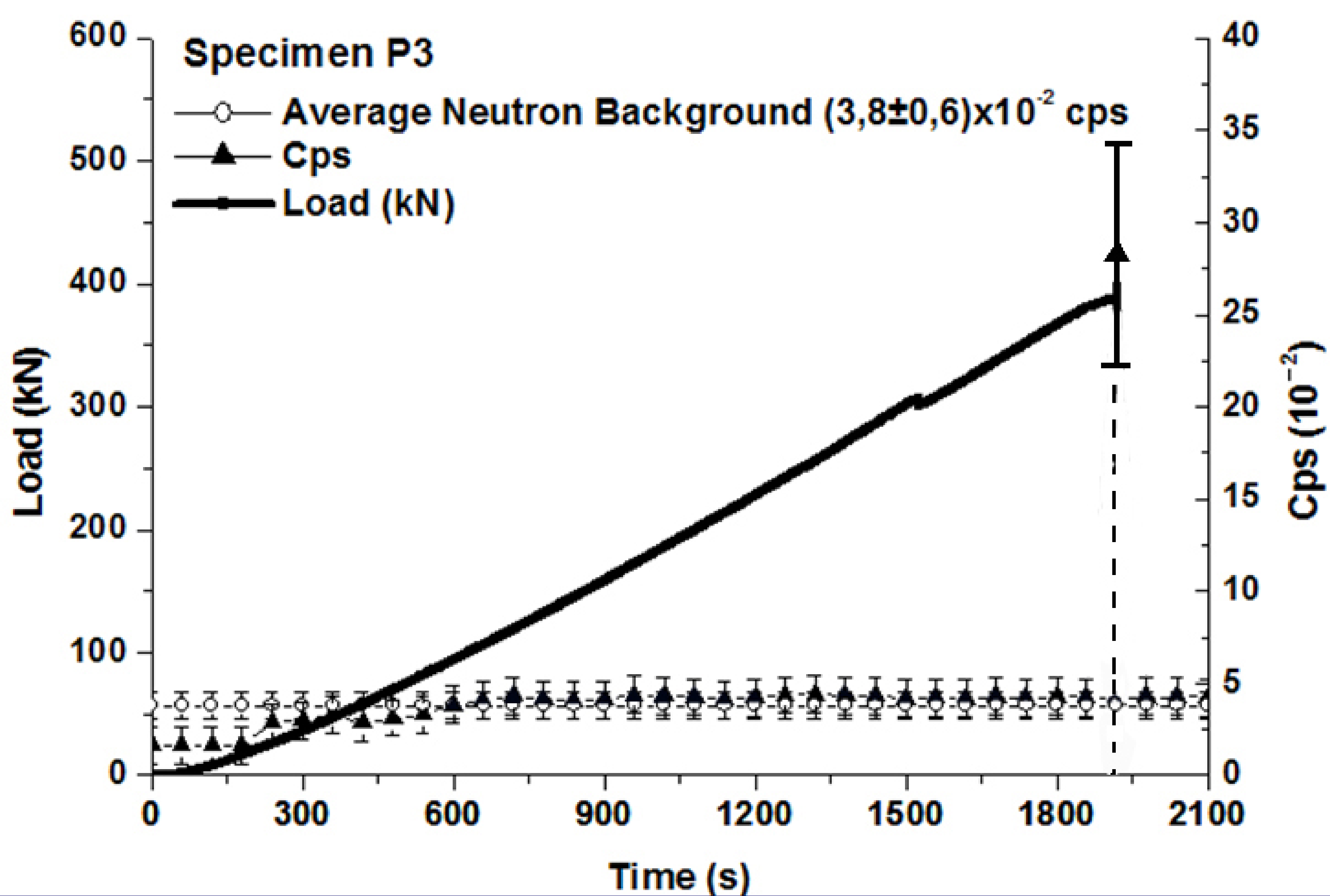
Specimens P3 e P4 in Luserna granite following compression failure.

Brittle Fracture Experiment on Carrara Marble specimen



Load vs. time and cps curve for P1 test specimen of Carrara marble.

Brittle Fracture Experiment on granite specimen

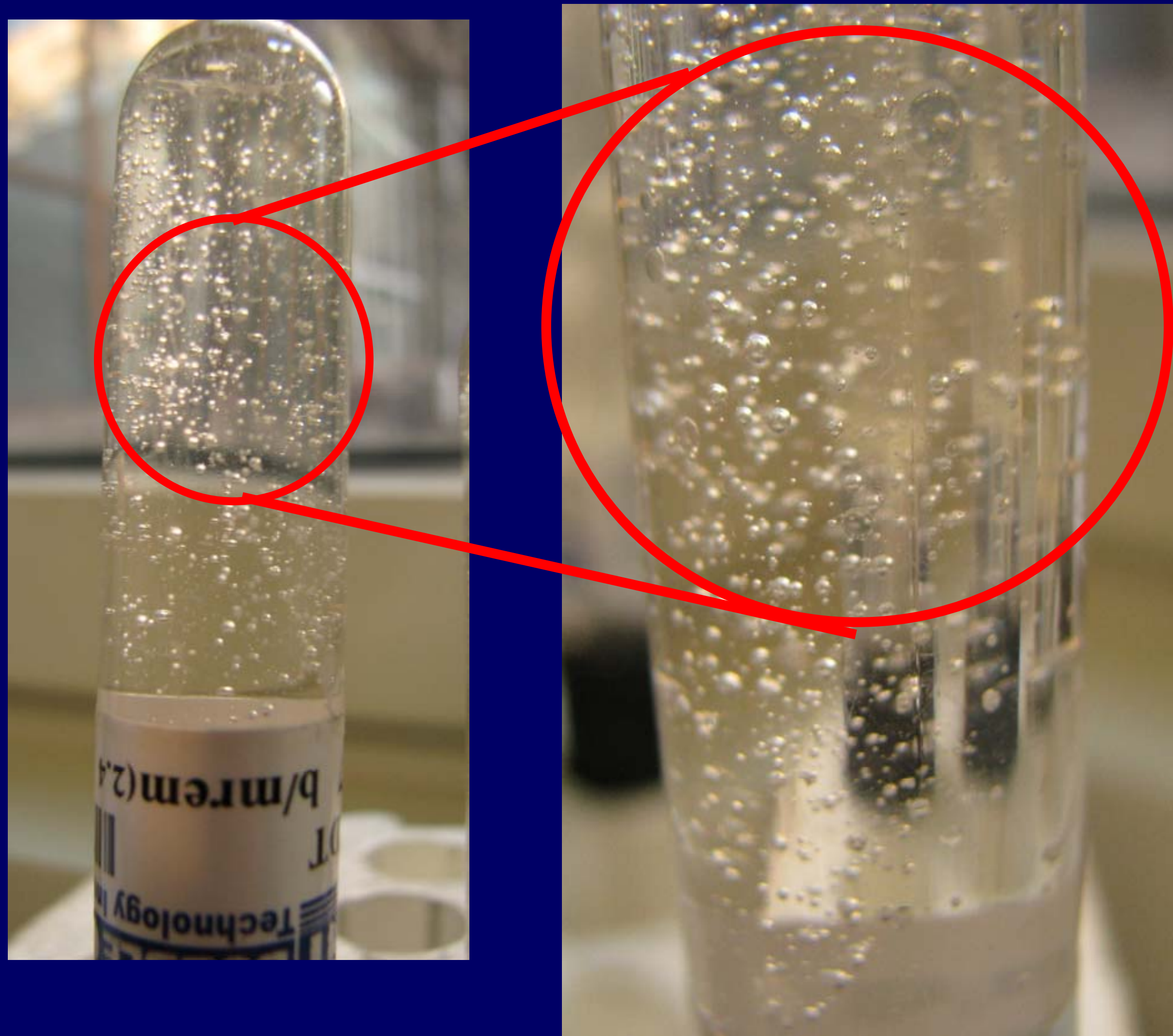


Load vs. time and cps curve for P3 test specimen of granite.

NEUTRON EMISSION FROM CAVITATION IN LIQUIDS AND FRACTURE IN SOLIDS

MATERIAL	NEUTRON EMISSION
LIQUIDS – Cavitation	
Iron chloride	→ **up to 2.5 times the Background Level**
SOLIDS – Fracture	
Steel	→ **up to 2.5 times the Background Level**
Granite (Fe ~ 1.5%)	→ **up to 10^1 times the Background Level**
Basalt (Fe ~ 15%)	→ **up to 10^2 times the Background Level**
Magnetite (Fe ~ 75%)	→ **up to 10^3 times the Background Level**
Marble	→ **Background Level**

Cyclic Loading Experiments on Basaltic Rocks



The equivalent neutron dose, at the end of the test on basaltic rock, was 2.62 ± 0,53 μSv/h (Average Background Dose = 41.95 ± 0,85 nSv/h).

$$\frac{\text{Effective Neutron Dose}}{\text{Average Background Dose}} \cong 50$$

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J. Phys. G: Nucl. Part. Phys. **40** (2013) 015006 (8pp) doi:10.1088/0954-3899/40/1/015006

Neutron production from the fracture of piezoelectric rocks

A Widom[1], J Swain[1] and Y N Srivastava[2]

[1] Physics Department, Northeastern University, Boston MA, USA
[2] Department of Physics & INFN, University of Perugia, Perugia, Italy

E-mail: John.Swain@cern.ch

Received 2 March 2012
Published 14 December 2012
Online at stacks.iop.org/JPhysG/40/015006

Abstract

A theoretical explanation is provided for the experimental evidence that fracturing piezoelectric rocks produces neutrons. The elastic energy micro-crack production ultimately yields the macroscopic fracture. The mechanical energy is converted by the piezoelectric effect into electric field energy. The electric field energy decays via radio frequency (microwave) electric field oscillations. The radio frequency electric fields accelerate the condensed matter electrons which then collide with protons producing neutrons and neutrinos.

Photo-Disintegration of the Iron Nucleus in Fractured Magnetite Rocks with Magnetostriction

A. Widom and J. Swain
Physics Department, Northeastern University, Boston MA USA

Y.N. Srivastava
Physics Department & INFN, University of Perugia, Perugia IT

There has been considerable interest in recent experiments on iron nuclear disintegrations observed when rocks containing such nuclei are crushed and fractured. The resulting nuclear transmutations are particularly strong for the case of magnetite rocks, i.e. loadstones. We argue that the fission of the iron nucleus is a consequence of photo-disintegration. The electro-strong coupling between electromagnetic fields and nuclear giant dipole resonances are central for producing observed nuclear reactions. The large electron energies produced during the fracture of piezomagnetic rocks are closely analogous to the previously discussed case of the fracture of piezoelectric rocks. In both cases electro-weak interactions can produce neutrons and neutrinos from energetic protons and electrons thus inducing nuclear transmutations. The electro-strong condensed matter coupling discussed herein represents new many body collective nuclear photo-disintegration effects.

PACS numbers: 62.20.mm, 81.40.Np, 03.75.Be, 14.20.Dh

EVIDENCE FOR PHOTOFISSION OF IRON*

C. B. Fulmer, I. R. Williams, and T. H. Handley
Oak Ridge National Laboratory, Oak Ridge, Tennessee

and

G. F. Dell and L. N. Blumberg†
Cambridge Electron Accelerator, Cambridge, Massachusetts
(Received 4 August 1967)

Studies of proton-induced reactions in the GeV energy region[1,2] have given evidence that fission occurs in nuclei at least as light as silver. It has been pointed out that any nucleus can be made to undergo fission provided it is supplied with sufficient excitation energy.[3,4] In this note we present evidence of photofission in iron foils that were bombarded with high-energy electrons.

that were bombarded with 3-GeV electrons an appreciable yield of ^{7}Be was observed.[5] Careful examination of the gamma spectra obtained from the iron targets yielded no evidence for ^{7}Be. A radiochemical separation also yielded no evidence for ^{7}Be in an iron foil that was bombarded with 3-GeV electrons. Studies of proton- and alpha-induced reactions[6] have shown that emission of ^{7}Be is enhanced by rotation-

PHYSICAL REVIEW VOLUME 82, NUMBER 5 JUNE 1, 1951

Fission of Medium Weight Elements*

ROGER E. BATZEL AND GLENN T. SEABORG
Radiation Laboratory and Department of Chemistry, University of California, Berkeley, California
(Received February 19, 1951)

Evidence is presented here which indicates that large fragments (much larger than alpha-particles) are emitted among the competitive products of transmutation throughout the entire range of atomic numbers of the elements. Threshold considerations for the observed nuclear reactions show that the reactions are observed with small cross sections well below the threshold for spallation reactions in which the maximum number of alpha-particles are considered as being emitted from the excited nucleus. The calculated thresholds include the mass difference between the reactants and the products and the excitation energy which the product particles or fragments must have in order to pass over the coulombic barrier. Preliminary experiments on the ranges of recoil fragments from copper irradiated with 340-Mev protons give additional evidence for the emission of heavy fragments. It is suggested that the term "fission" is proper for such reactions, throughout the entire range of atomic numbers, in which the nucleus is split essentially into pieces of comparable weight.

I. INTRODUCTION

THE fission reaction has been observed with high energy accelerator projectiles for elements as light as tantalum,[1] but has not been reported for medium weight elements. Evidence is presented here for occurrence of reactions which are probably most

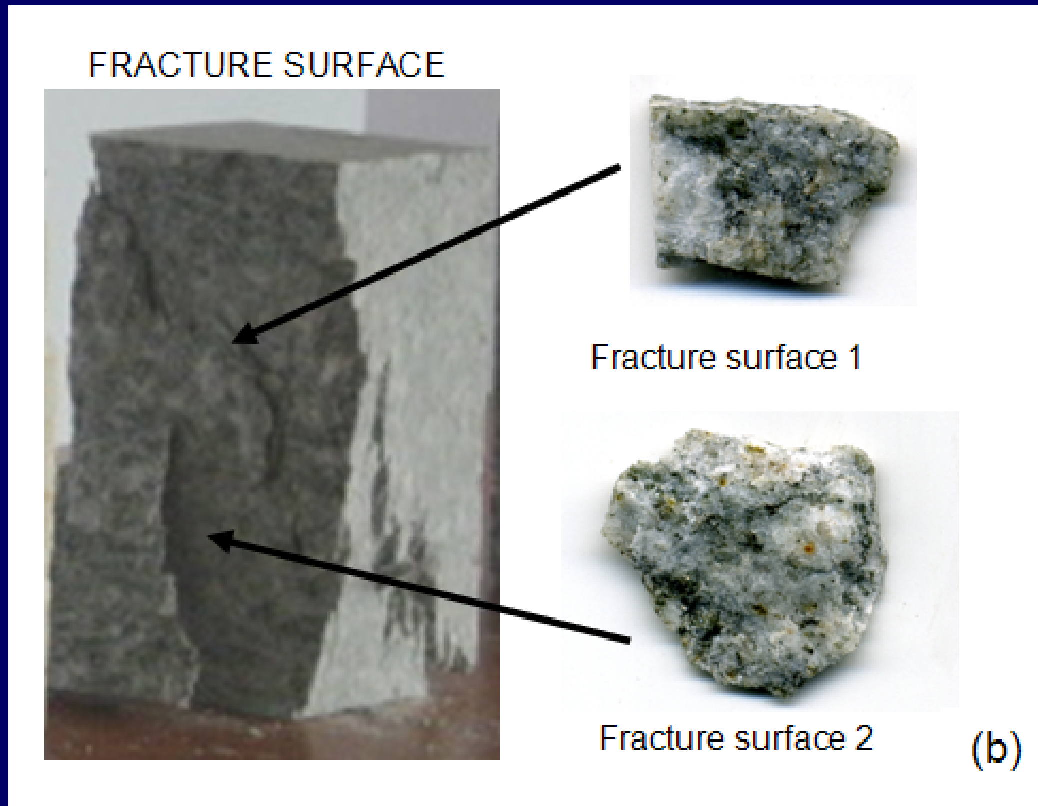
an example, the extreme reaction $Cu^{63}+p\rightarrow Cl^{38}+Al^{25}+n$, which is energetically most economical but still endoergic, has a threshold of about 50 Mev.

This result made it seem worthwhile to investigate another such reaction in copper and to extend the threshold studies to other elements in the middle portion

CHEMICAL COMPOSITION CHANGES AT THE LABORATORY SCALE

ENERGY DISPERSIVE X-RAY SPECTROSCOPY: COMPOSITIONAL ANALYSIS OF PRODUCT ELEMENTS

Two different kinds of samples were examined: (i) polished thin sections from the external surface; (ii) small portions from the fracture surface.



A quantitative analysis was performed on the collected spectra in order to recognize specific **variations in each element between external and fracture surfaces**.

Phengite (Granite)

	External surface mean value (wt%)	Fracture surface mean value (wt%)	Increase/ decrease with respect to phengite	Increase/ decrease with respect to the same element
Fe	6.2	4.0	–2.2%	–35%
Al	12.5	14.5	+2.0%	+16%
Si	28.0	27.8	NO VARIATIONS	NO VARIATIONS
Mg	0.7	0.8	NO VARIATIONS	NO VARIATIONS
K	8.0	7.7	NO VARIATIONS	NO VARIATIONS

$$Fe^{56}_{26} \rightarrow 2\,Al^{27}_{13} + 2\,n$$

Biotite (Granite)

	External surface mean value (wt%)	Fracture surface mean value (wt%)	Increase/ decrease with respect to biotite	Increase/ decrease with respect to the same element
Fe	21.2	18.2	–3.0 %	–14%
Al	8.1	9.6	+1.5 %	+18%
Si	18.4	19.6	+1.2 %	+6%
Mg	1.5	2.2	+0.7 %	+46%
K	6.9	7.1	NO VARIATIONS	NO VARIATIONS

$$Fe_{26}^{56} \rightarrow 2\,Al_{13}^{27} + 2n$$

$$Fe_{26}^{56} \rightarrow Si_{14}^{28} + Mg_{12}^{24} + 4n$$

Olivine (Basalt)

	External surface mean value (wt%)	Fracture surface mean value (wt%)	Increase/decrease with respect to Olivine	Increase/decrease with respect to the same element
Fe	18.4	14.4	–4.0%	–21%
Si	18.3	20.5	+2.2%	+12%
Mg	21.2	22.8	+1.6%	+7%
Ca	0.5	0.5	NO VARIATIONS	NO VARIATIONS

$$Fe^{56}_{26} \rightarrow Si^{28}_{14} + Mg^{24}_{12} + 4n$$

Magnetite

	External surface mean value (wt%)	Fracture surface mean value (wt%)	Increase/decrease with respect to Magnetite	Increase/decrease with respect to the same element
Fe	64.8	36.8	−27.9%	−56%
Al	–	10.1	+10.1%	BEFORE ABSENT
Mn	–	2.2	+2.2%	BEFORE ABSENT
Si	1.6	10.3	+8.7%	+540%
O	31.8	38.5	+6.7%	+21%

$$Fe^{56}_{26} \rightarrow 2\,Al^{27}_{13} + 2\,n$$

$$Fe^{56}_{26} \rightarrow Mn^{55}_{25} + H^{1}_{1}$$

$$Fe^{56}_{26} \rightarrow Si^{28}_{14} + O^{16}_{8} + 2He^{4}_{2} + 4n$$

Carrara Marble

	External surface mean value (wt%)	Fracture surface mean value (wt%)	Increase/ decrease with respect to Carrara Marble	Increase/ decrease with respect to the same element
Ca	13.4	9.8	–3.6 %	–26%
Mg	0.7	0.3	–0.4 %	–57%
O	45.8	36.8	–9.0 %	–19%
C	40.1	53.1	+13.0%	+32%

$$Ca_{20}^{40} \rightarrow 3C_{6}^{12} + He_{2}^{4}$$

$$Mg_{12}^{24} \rightarrow 2C_{6}^{12}$$

$$O_{8}^{16} \rightarrow C_{6}^{12} + He_{2}^{4}$$

MICRO-CRACKING

&

FRACTURE IN ELECTROLYSIS ELECTRODES

RECURRING PHENOMENA IN THE SO-CALLED COLD FUSION (CF)

- 1989 - Fleishman & Pons → Heat Generation
- 1998 - Mizuno → Heat Generation
  Neutron Emission
  Compositional changes
- 2008 - Mosier-Boss et al. → Heat Generation
  Neutron Emission
  Compositional changes
  Alpha particle emissions

Fleischmann, Pons, Hawkins, 1989. J. Electroanalitical Chemistry

Mizuno, 1998. Infinite Energy Press.

Mosier-Boss, P.A., et al., 2008. Eur. J. of Applied Physics

Cold Fusion vs Piezonuclear Reactions ?

"A unified interpretation and theory of these phenomena has not been accepted and their comprehension still remains unresolved" (***Preparata 1991***)

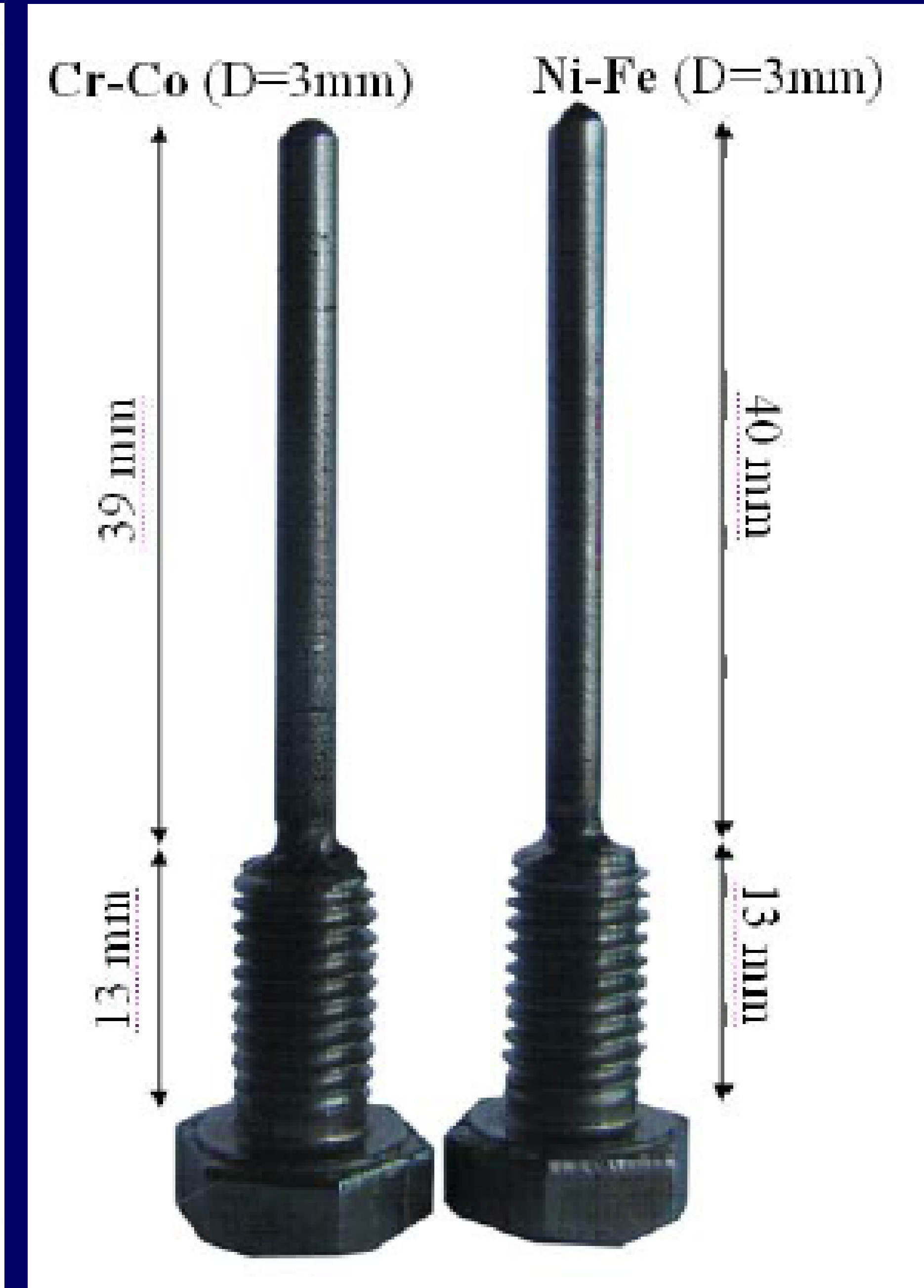
Is there a relation between the experimental evidence of the so-called "Cold Fusion", observed during the last two decades, and the Piezonuclear evidence recently observed from fracture of inert and nonradioactive materials?

Phenomena in common :

- **Neutron Emission**
- **Alpha Emission**
- **Compositional Changes**
- **Microcracking and Fracture**

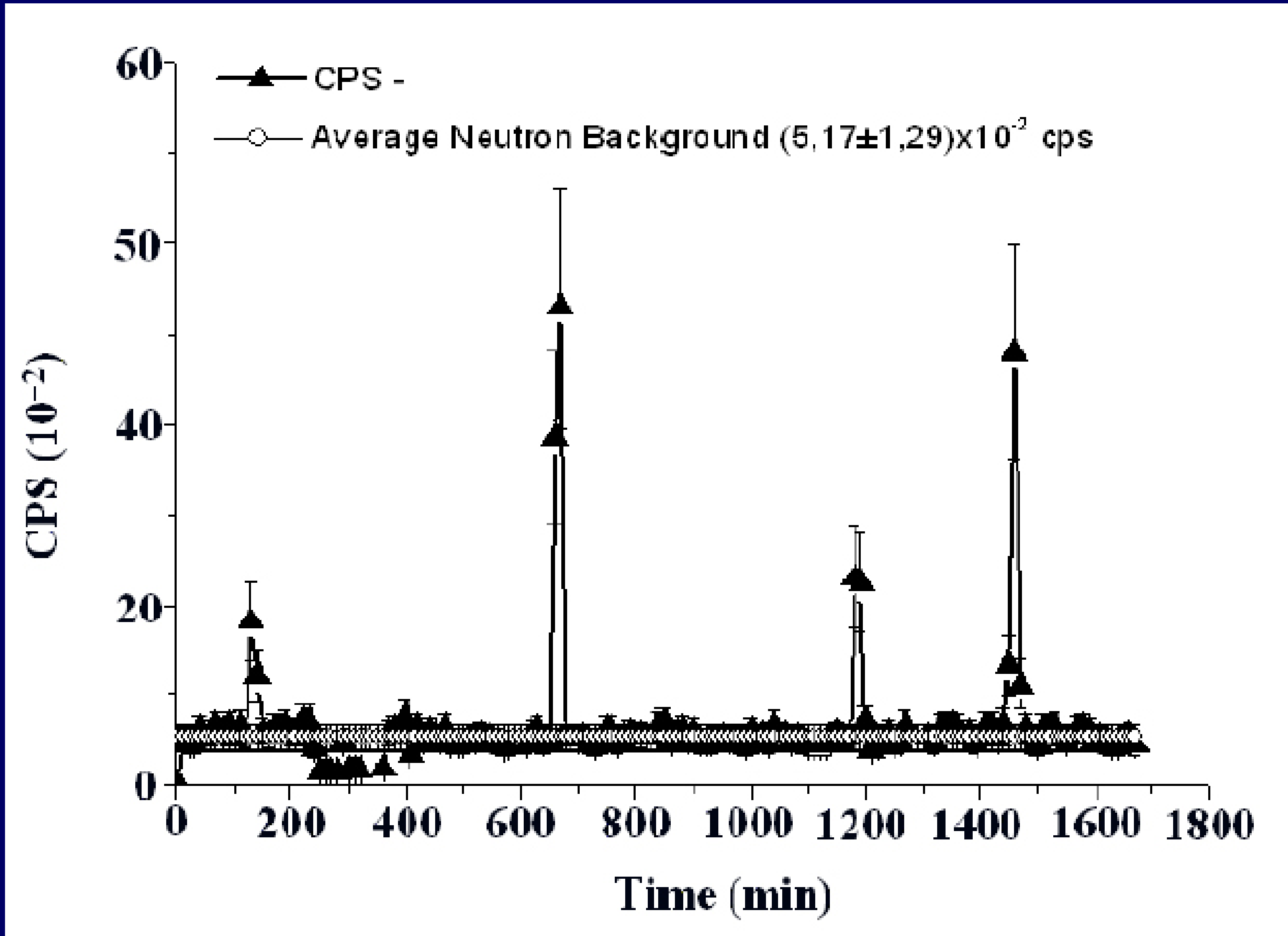
Experimental Set-up

Electrolytic Cell



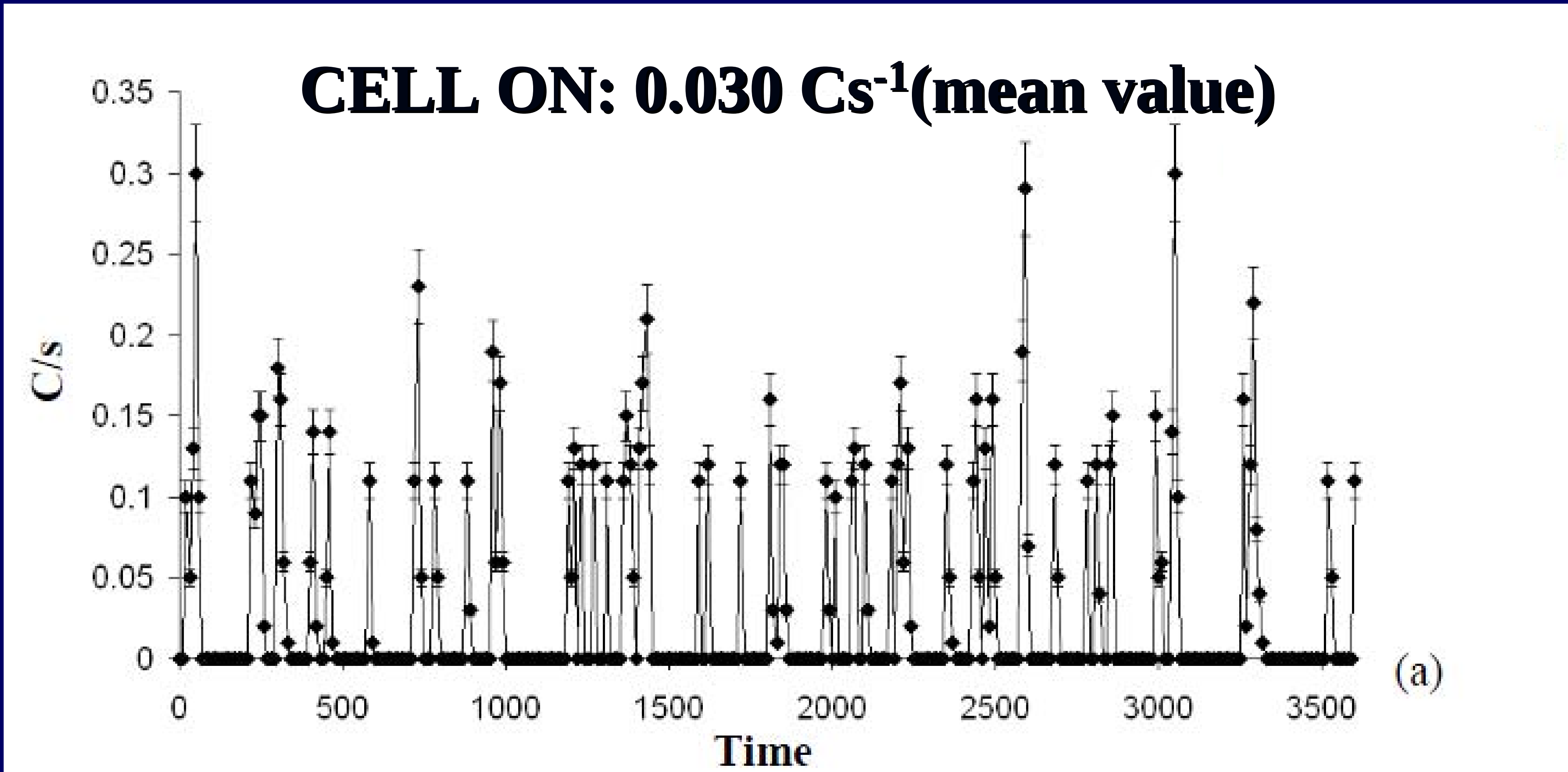
Electrodes

Neutron Emission



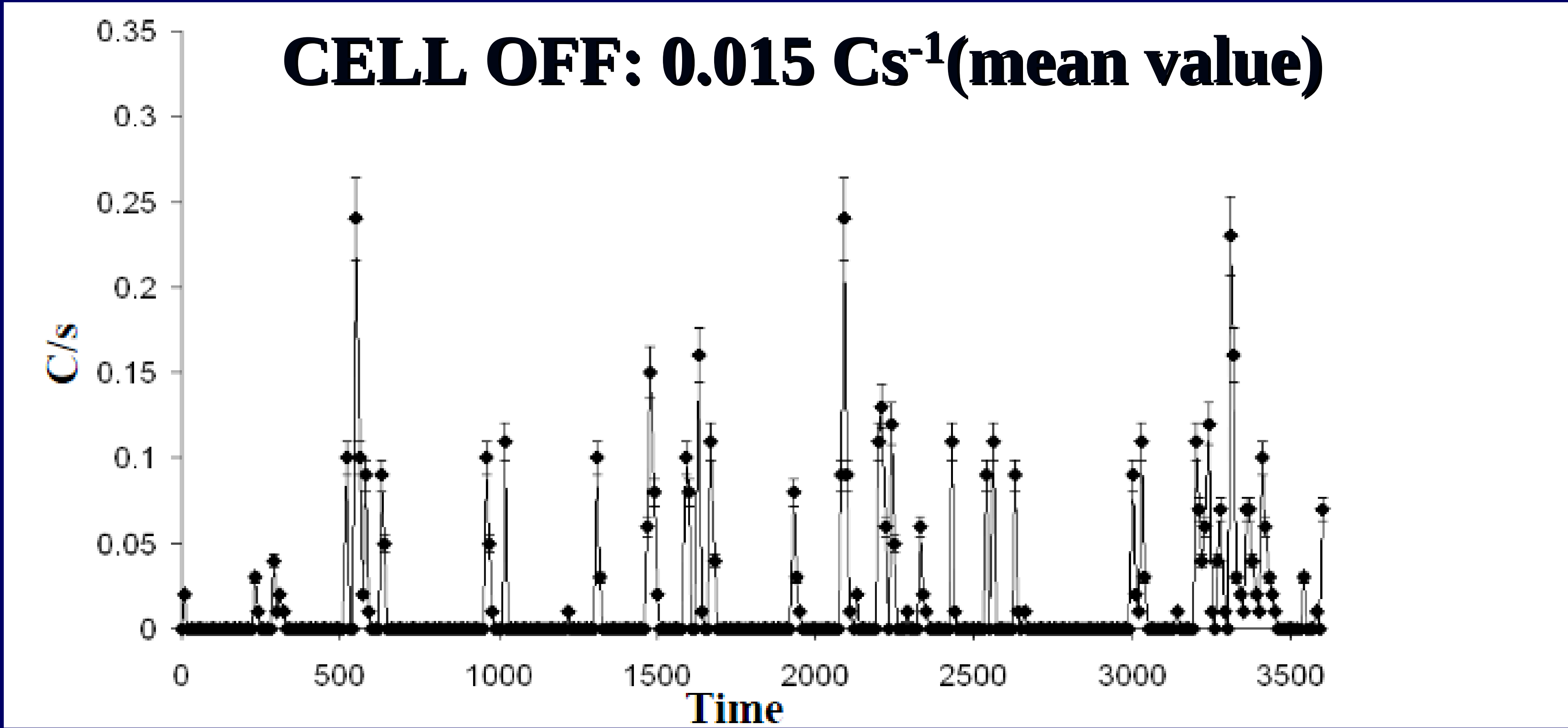
Instantaneous Neutron Emission between 4 times and 10 times the background level

Alpha Particle Emission



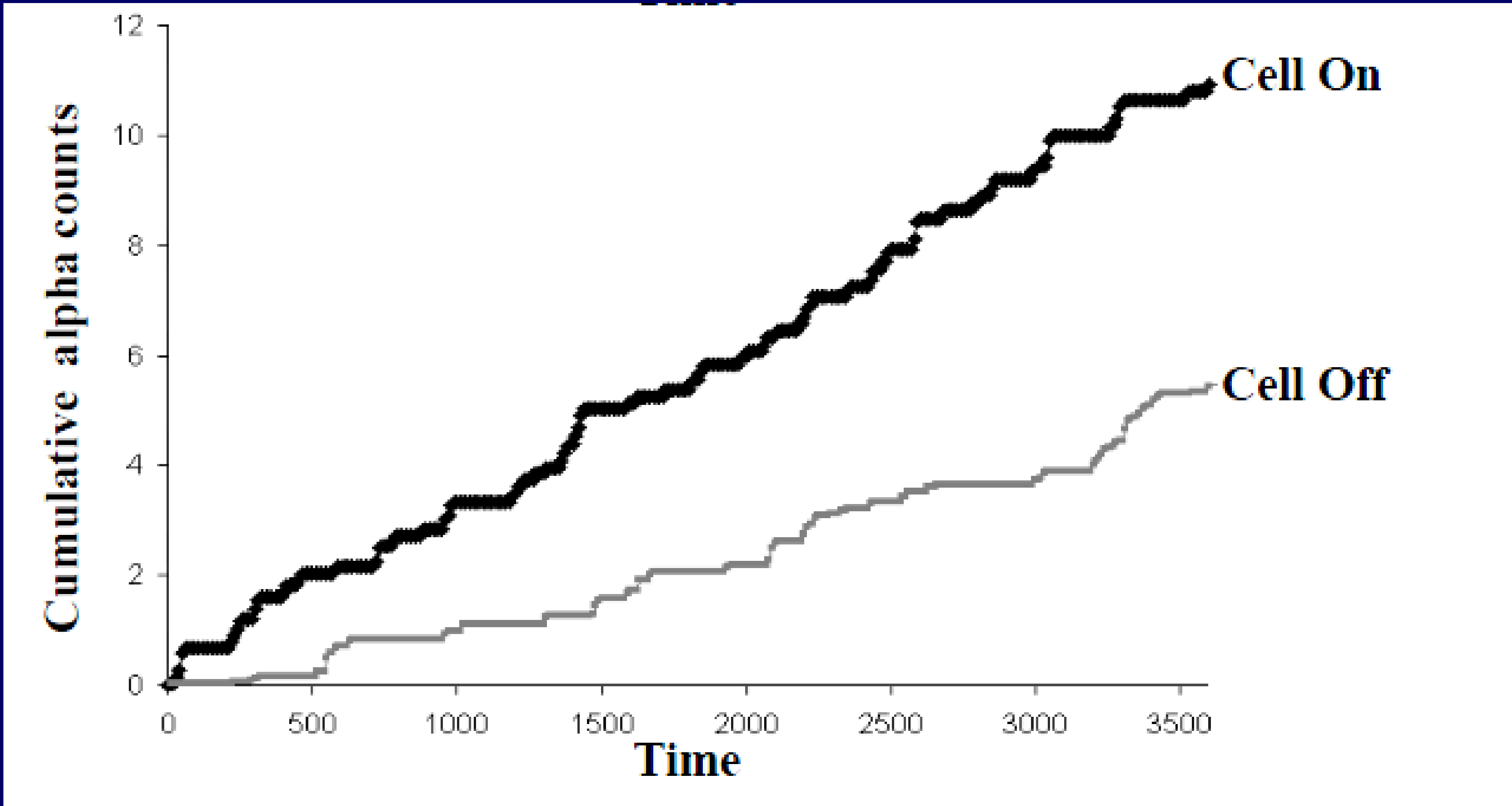
Total acquisition time: 1 hour

Alpha Particle Emission

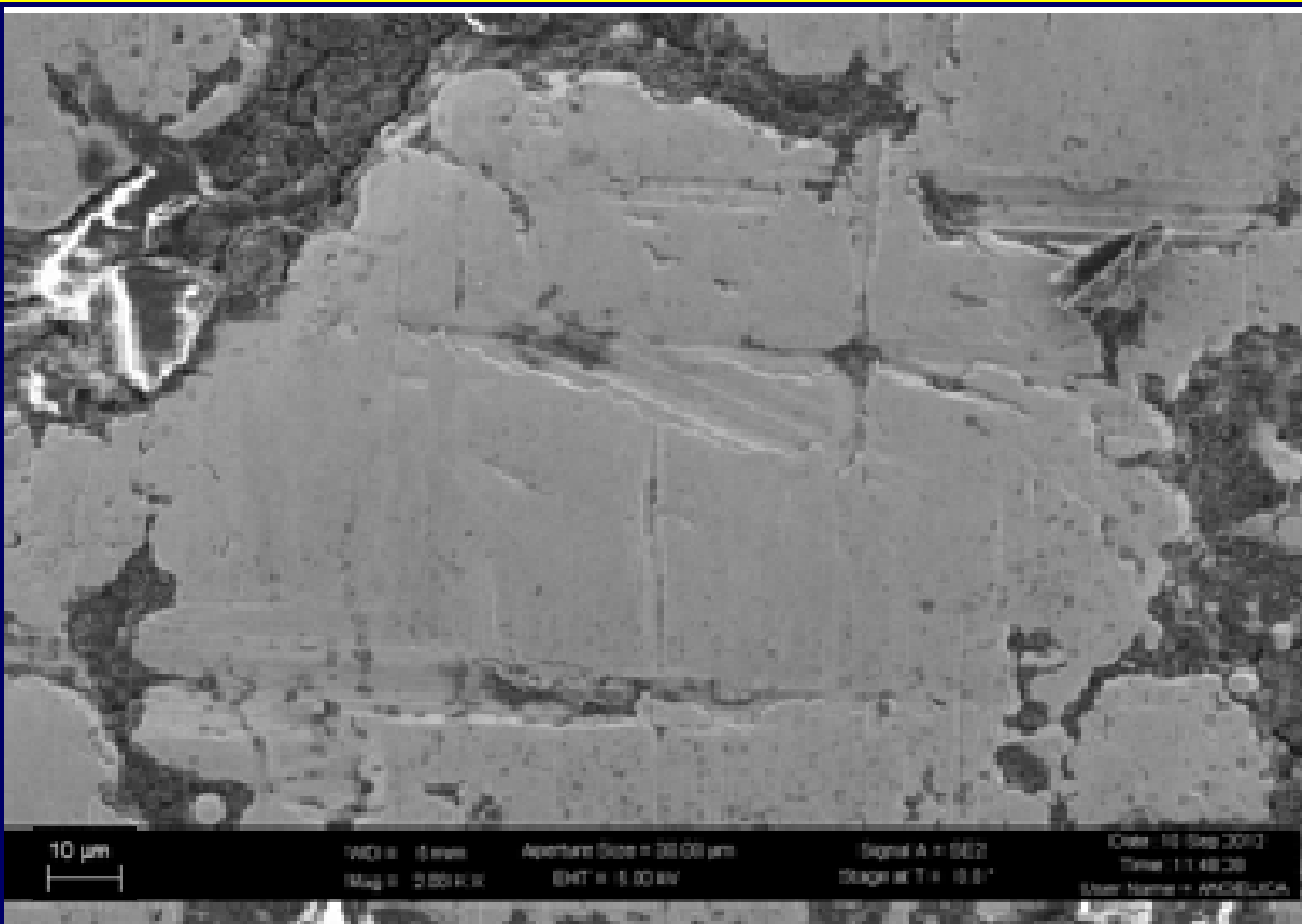


Total acquisition time: 1 hour

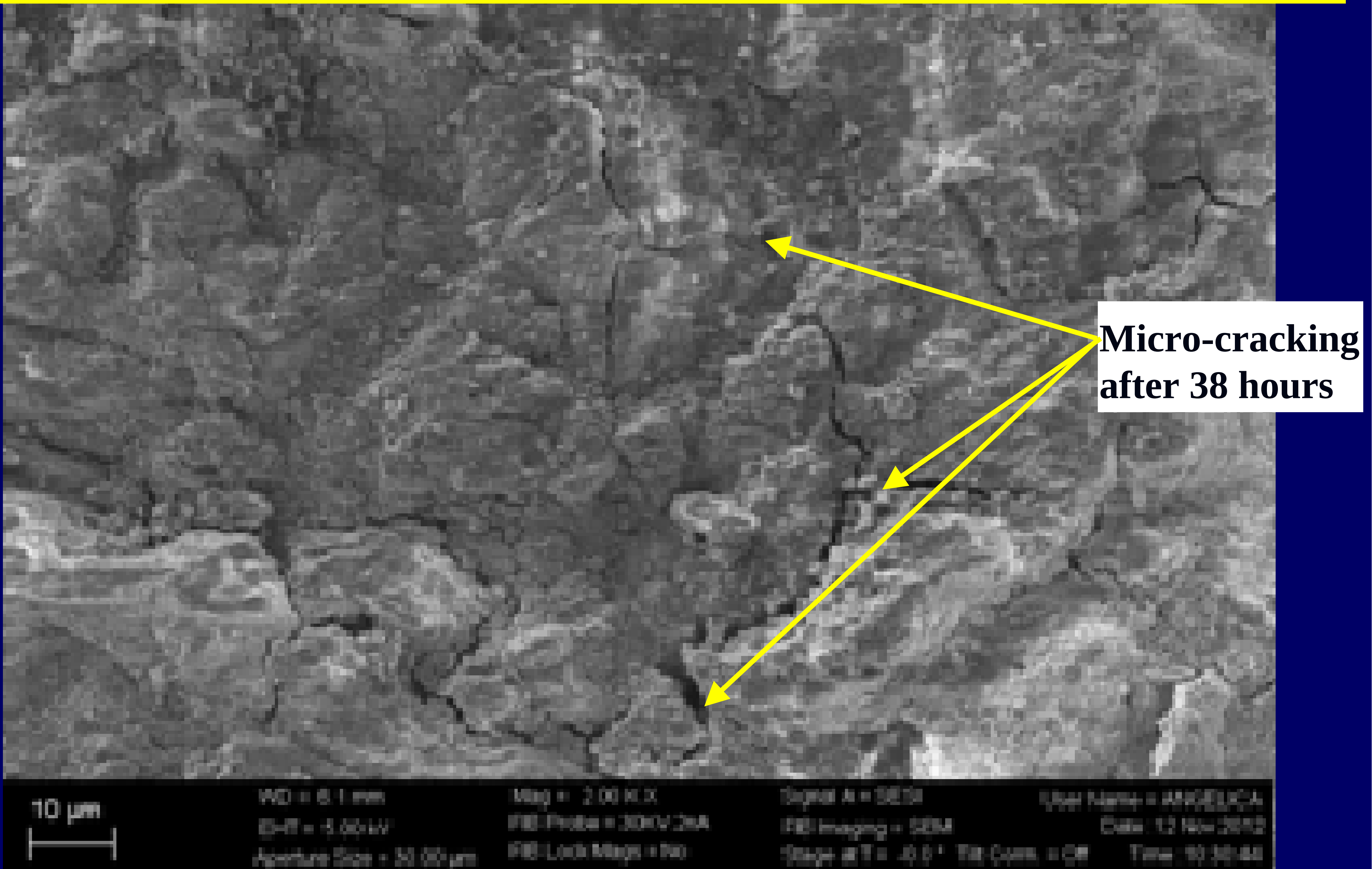
Cumulative Curves for the Alpha Emissions

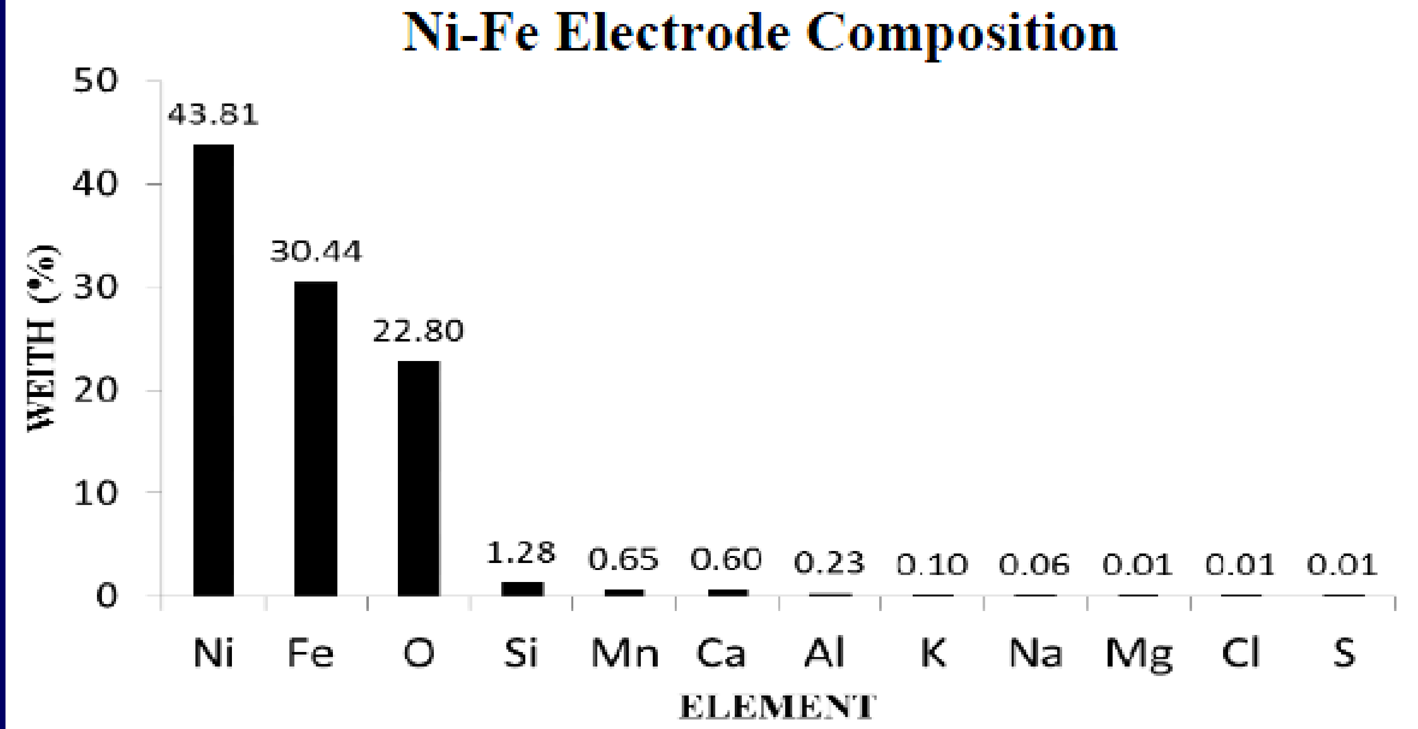


Co-Cr electrode surface BEFORE the test

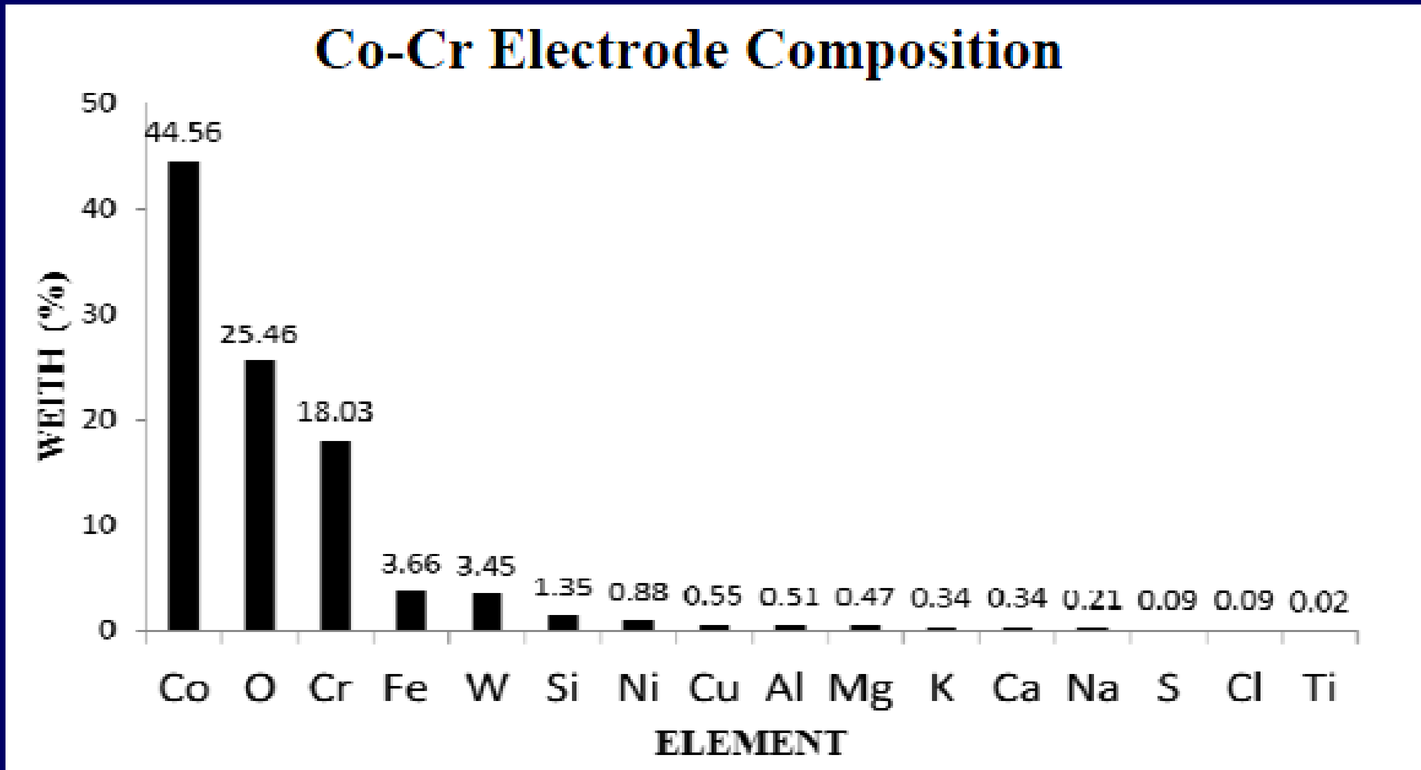


Co-Cr electrode surface AFTER the test





Ni-Fe Electrode Composition
WEITH (%)
50
40
30
20
10
0
43.81
30.44
22.80
1.28
0.65
0.60
0.23
0.10
0.06
0.01
0.01
0.01
Ni
Fe
O
Si
Mn
Ca
Al
K
Na
Mg
Cl
S
ELEMENT



Co-Cr Electrode Composition
WEITH (%)
50
40
30
20
10
0
44.56
25.46
18.03
3.66
3.45
1.35
0.88
0.55
0.51
0.47
0.34
0.34
0.21
0.09
0.09
0.02
Co
O
Cr
Fe
W
Si
Ni
Cu
Al
Mg
K
Ca
Na
S
Cl
Ti
ELEMENT

Electrode Ni-Fe: Compositional Changes

	Mean Values*				
Experiment	**Ni**	**Si**	**Mg**	**Fe**	**Cr**
After 0 h	43.9%	1.1%	0.1%	30.5%	-
After 4h	43.6%	0.5%	0.4%	30.7%	-
After 32h	35.2%	5.0%	0.2%	27.9%	-
After 38h	35.3%	1.5%	4.8%	27.3%	3.0%

Ni (–8.6%) = Si (+3.9%) +Mg (+4.7%)

$$Ni^{58}_{28} \rightarrow 2Si^{28}_{14} + 2n$$

$$Ni^{58}_{28} \rightarrow 2Mg^{24}_{12} + 2He^{4}_{2} + 2n$$

Fe (–3.2%) = Cr (+3.0%)

$$Fe^{56}_{26} \rightarrow Cr^{52}_{24} + He^{4}_{2}$$

Electrode Co-Cr: Compositional Changes

Experiment	Co	Fe	Cr	K
After 0 h	44.1%	3.1%	17.8%	0.5%
After 4h	43.7%	1.6%	17.8%	2.2%
After 32h	20.6%	26.3%	9.7%	12.9%

Co (–23.5%) = Fe (+23.2%)

$$Co_{27}^{59} \rightarrow Fe_{26}^{56} + H_1^1 + 2n$$

Cr (–8.1%) + K_2CO_3 (–4.3%) = K (+12.4%)

$$Cr_{24}^{52} \rightarrow K_{19}^{39} + 2He_2^4 + H_1^1 + 4n$$

CONCLUSIONS

Two piezonuclear fission reaction jumps typical of the Earth Crust:

$$Fe_{26}, Co_{27}, Ni_{28} \longrightarrow Mg_{12}, Al_{13}, Si_{14} \longrightarrow C_6, N_7, O_8$$

Explanation for:

- Production of **NEUTRONS** (Rn, CO_2) during earthquakes
- **STEP-WISE TIME VARIATIONS** in the most abundant elements (including Na_{11}, K_{19}, Ca_{20})
- **SPACE LOCALIZATION** of the resources on the Earth's Crust
- Very high **CARBON** content in the primordial atmosphere
- Great Oxidation Event (2.5 Billion years ago), **OCEAN FORMATION** and origin of life

- Evolution of the planets of the **SOLAR SYSTEM**: Mercury, Mars, Jupiter, Saturn (and the Sun itself)

- The so-called **COLD NUCLEAR FUSION** may be explained by piezonuclear fission reactions occurring in the electrodes and due to **HYDROGEN EMBRITTLEMENT,** rather than by fusion of hydrogen isotopes

POSSIBLE APPLICATIONS

- Precurring and monitoring of **Earthquakes**
- Correct evaluation of **Carbon Pollution** & **Climate Changes**
- Production of **Clean energy** (?)

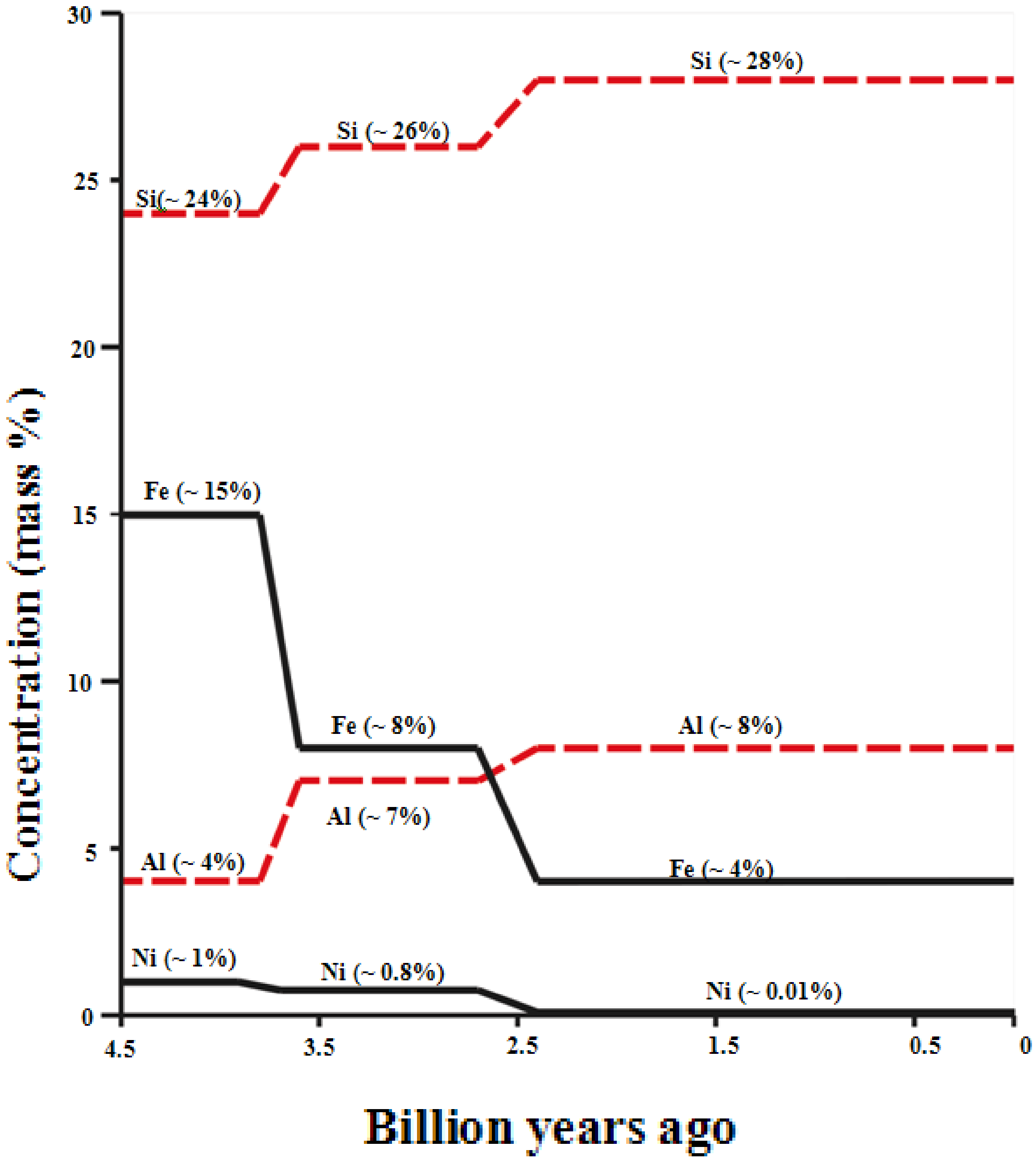
APPENDIX A

IRON DEPLETION

vs

CARBON POLLUTION

TECTONIC ACTIVITY vs CHEMICAL EVOLUTION



Tectonic plate formation

(3.8 Billion years ago):

Fe (–7%) + Ni (–0.2%) =

=Al (+3%) + Si (+2.2%) + Mg (+2%)

Most severe tectonic activity

(2.5 Billion years ago):

Fe (–4%) + Ni (–0.8%) =

=Al (+1%) + Si (+2.3%) + Mg (+1.5%)

Conjecture about ferrous elements' trasformations in the Earth Crust

$$(1)\ Fe^{56}_{26} \rightarrow 2\,Al^{27}_{13} + 2n$$

$$(2)\ Fe^{56}_{26} \rightarrow Si^{28}_{14} + Mg^{24}_{12} + 4n$$

$$(3)\ Fe^{56}_{26} \rightarrow Ca^{40}_{20} + C^{12}_{6} + 4n$$

$$(4)\ Co^{59}_{27} \rightarrow Si^{28}_{14} + Al^{27}_{13} + 4n$$

$$(5)\ Ni^{59}_{28} \rightarrow 2\,Si^{28}_{14} + 3n$$

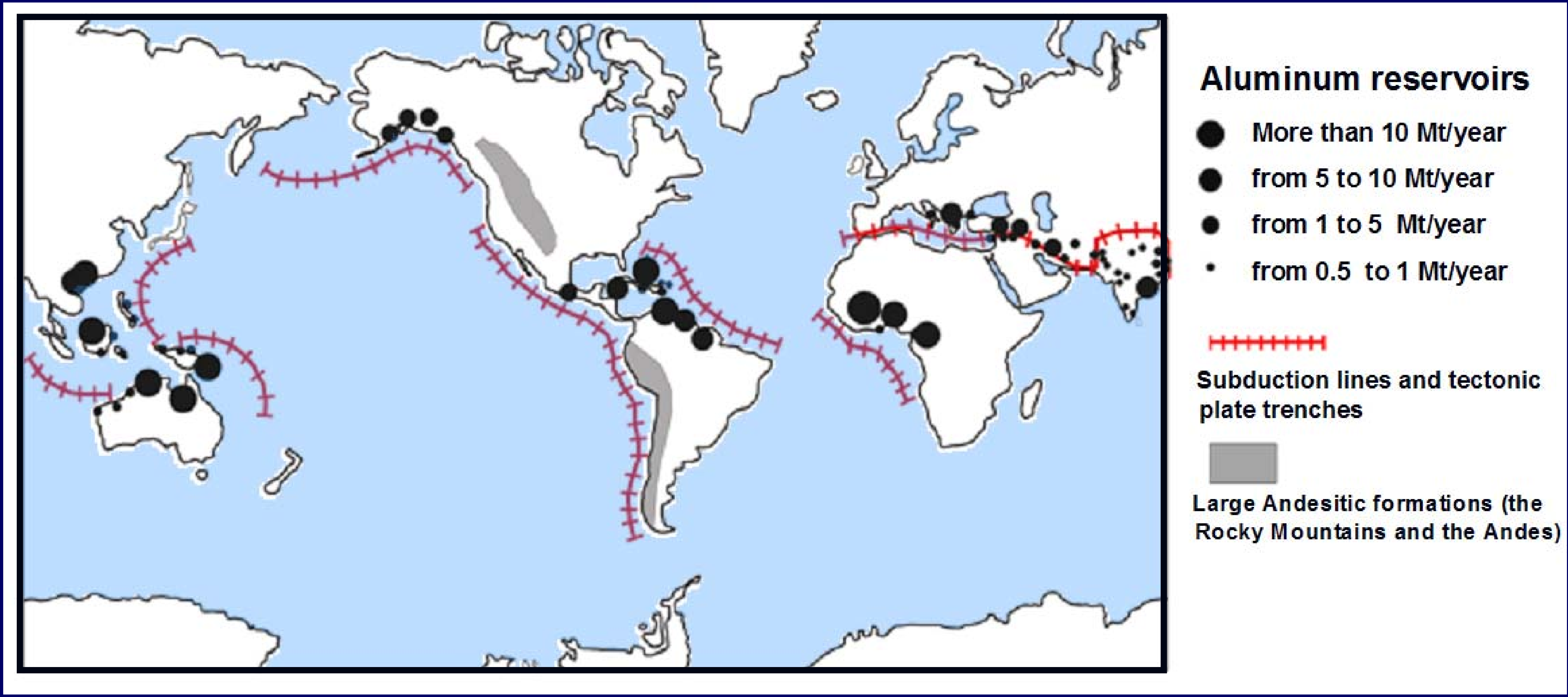
$$(6)\ Ni^{59}_{28} \rightarrow Na^{23}_{11} + Cl^{35}_{17} + 1n$$

Localization of iron mines

(*) World Iron Ore producers. Available at http://www.mapsofworld.com/minerals/world-iron-ore-producers.html.

(**) World Mineral Resources Map. Available at http://www.mapsofworld.com/world-mineral-map.html.

Localization of Aluminum mines



(*) World Iron Ore producers. Available at http://www.mapsofworld.com/minerals/world-iron-ore-producers.html.

(**) World Mineral Resources Map. Available at http://www.mapsofworld.com/world-mineral-map.html.

Magnesium depletion and Carbon concentration in the primordial atmosphere

The estimated Mg increase (~3.5%) is equivalent to the Carbon content in the primordial atmosphere:

$$Fe_{26}^{56} \rightarrow Mg_{12}^{24} + Si_{14}^{28} + 4n$$

$$Mg_{12}^{24} \rightarrow 2C_{6}^{12}$$

Assuming a mean density of the Earth Crust equal to 3.6 g/cm^3 and a thickness of ~60 km, the mass increase in Mg (~3.5×10^{21} kg), and therefore in C, implies a very high atmospheric pressure

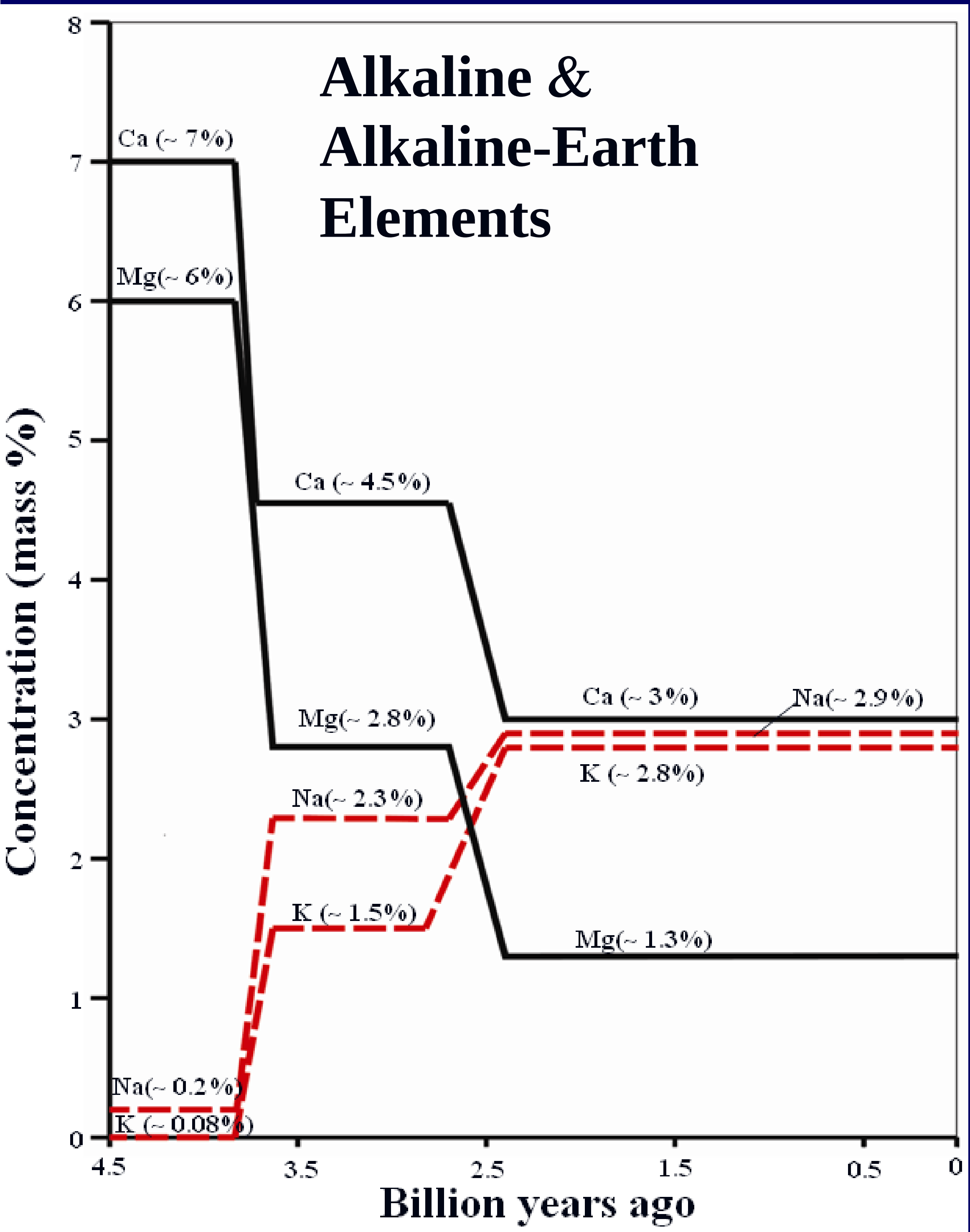
Primordial atmospheric pressure due to C increase = ~650 atm

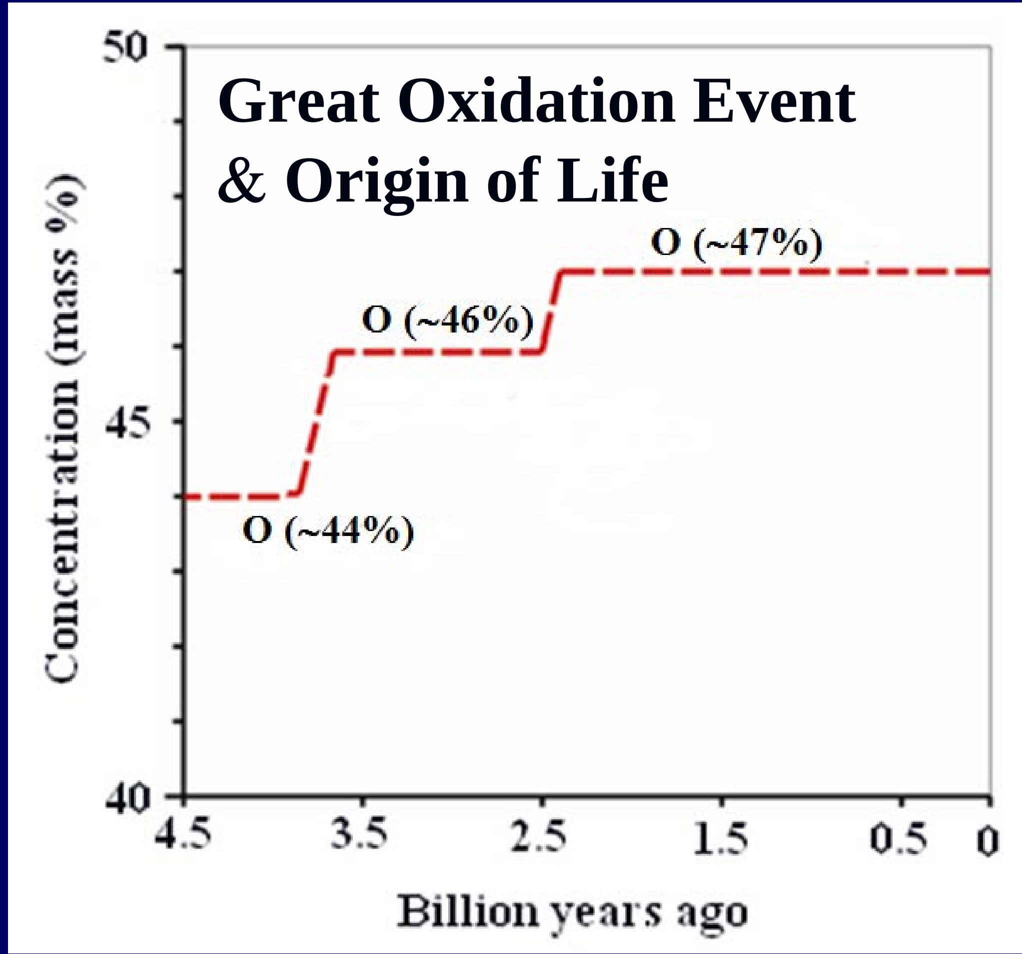
⟷

Primordial atmospheric pressure reported by other authors = ~650 atm (Liu, 2004)

Liu, L., "The inception of the oceans and CO_2-atmosphere in the early history of the Earth". *Earth Planet. Sci. Lett.*, 227, 179–184 (2004)

CALCIUM DEPLETION
vs
OCEAN FORMATION





3.8 Billion years ago:
Ca (–2.5%) + Mg(–3.2%) =
= K (+1.4%) + Na (+2.1%) + O (+2.2%)

2.5 Billion years ago:
Ca (–1.5%) + Mg(–1.5%) =
=K (+1.3%) + Na (+0.6%) + O (+1.1%)

Conjecture about Alkaline-Earth elements' transformations

(7) $Mg_{12}^{24} \rightarrow Na_{11}^{23} + H_1^1$

(8) $Mg_{12}^{24} \rightarrow O_8^{16} + 2H_1^1 + He_2^4 + 2n$

(9) $Mg_{12}^{24} \rightarrow 2C_6^{12}$

(10) $Ca_{20}^{40} \rightarrow K_{19}^{39} + H_1^1$

(11) $Ca_{20}^{40} \rightarrow 2O_8^{16} + 4H_1^1 + 4n$

(12) $Ca_{20}^{40} \rightarrow 3C_6^{12} + He_2^4$

Conjecture about Alkaline-Earth elements' transformations

(7) $\mathrm{Mg}^{24}_{12} \rightarrow \mathrm{Na}^{23}_{11} + \mathrm{H}^{1}_{1}$

(8) $\mathrm{Mg}^{24}_{12} \rightarrow \mathrm{O}^{16}_{8} + 2\mathrm{H}^{1}_{1} + \mathrm{He}^{4}_{2} + 2\mathrm{n}$

(9) $\mathrm{Mg}^{24}_{12} \rightarrow 2\mathrm{C}^{12}_{6}$

(10) $\mathrm{Ca}^{40}_{20} \rightarrow \mathrm{K}^{39}_{19} + \mathrm{H}^{1}_{1}$

(11) $\mathrm{Ca}^{40}_{20} \rightarrow 2\mathrm{O}^{16}_{8} + 4\mathrm{H}^{1}_{1} + 4\mathrm{n}$

(12) $\mathrm{Ca}^{40}_{20} \rightarrow 3\mathrm{C}^{12}_{6} + \mathrm{He}^{4}_{2}$

Primordial Atmosphere

Conjecture about Alkaline-Earth elements' transformations

(7) $$Mg_{12}^{24} \rightarrow Na_{11}^{23} + H_{1}^{1}$$

(8) $$Mg_{12}^{24} \rightarrow O_{8}^{16} + 2H_{1}^{1} + He_{2}^{4} + 2n$$

(9) $$Mg_{12}^{24} \rightarrow 2C_{6}^{12}$$

(10) $$Ca_{20}^{40} \rightarrow K_{19}^{39} + H_{1}^{1}$$

(11) $$Ca_{20}^{40} \rightarrow 2O_{8}^{16} + 4H_{1}^{1} + 4n$$

(12) $$Ca_{20}^{40} \rightarrow 3C_{6}^{12} + He_{2}^{4}$$

Ocean Formation

Calcium depletion and ocean formation

Global decrease in Ca (–4.0%) is counterbalanced by an increase in K (+2.7%) and in H_2O (+1.3%).

$$Ca_{20}^{40} \rightarrow K_{19}^{39} + H_1^1$$

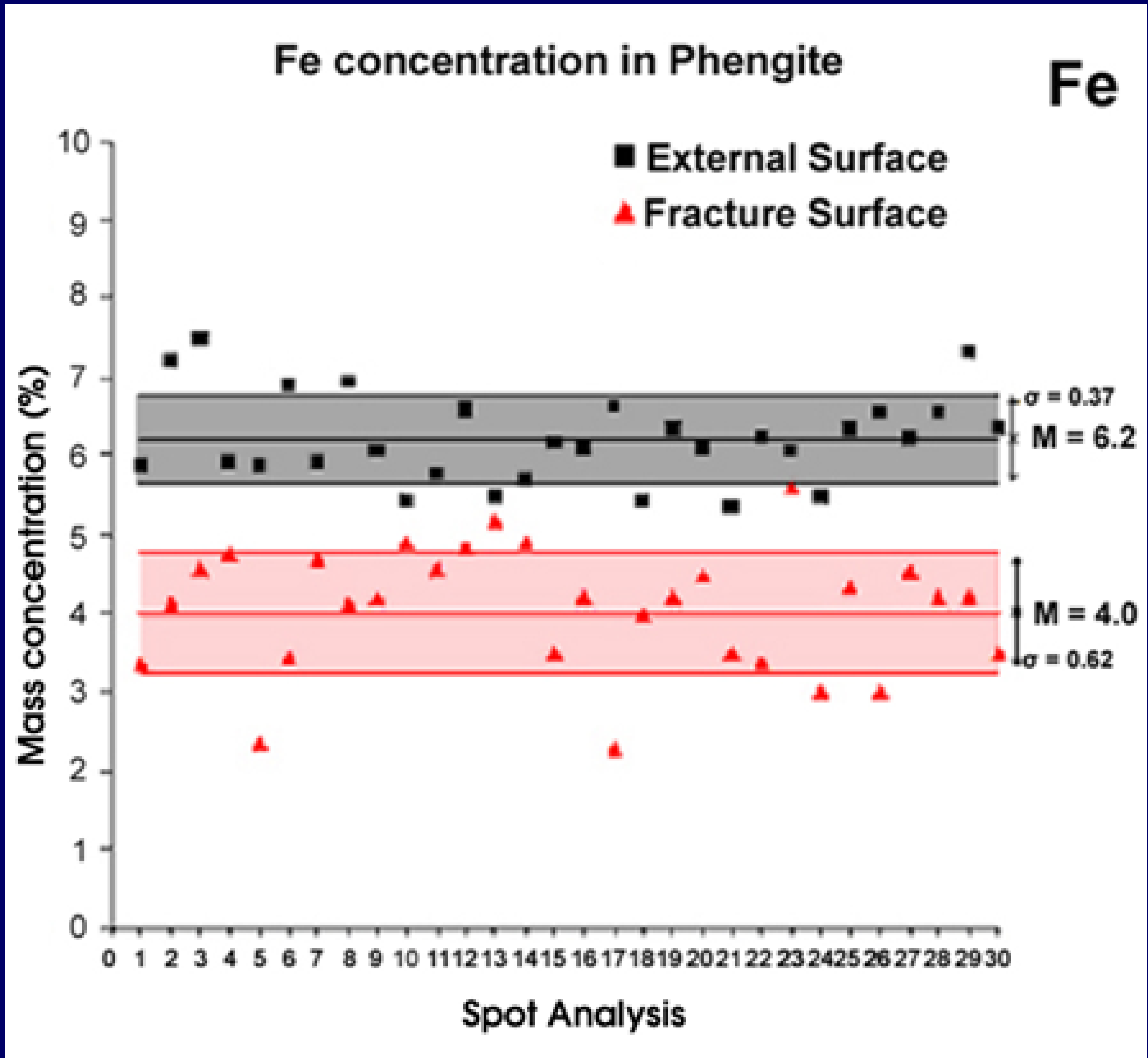
$$Ca_{20}^{40} \rightarrow 2O_8^{16} + 4H_1^1 + 4n$$

Assuming a mean density of the Earth Crust equal to 3.6 g/cm3 and a thickness of ~60 km, the partial mass decrease in Ca due to the second reaction is about 1.41×10^{21} kg.

Considering a global ocean surface of 3.61×10^{14} m^2, and an average depth of 3950 m, we obtain a mass of water of about 1.35×10^{21} kg

Partial decrease in Ca 1.41×10^{21} kg ⟷ **Mass of H_2O in the oceans today 1.35×10^{21} kg**

Phengite (Granite) : Fe concentrations



External Surf.:

Fe content = 6.2%

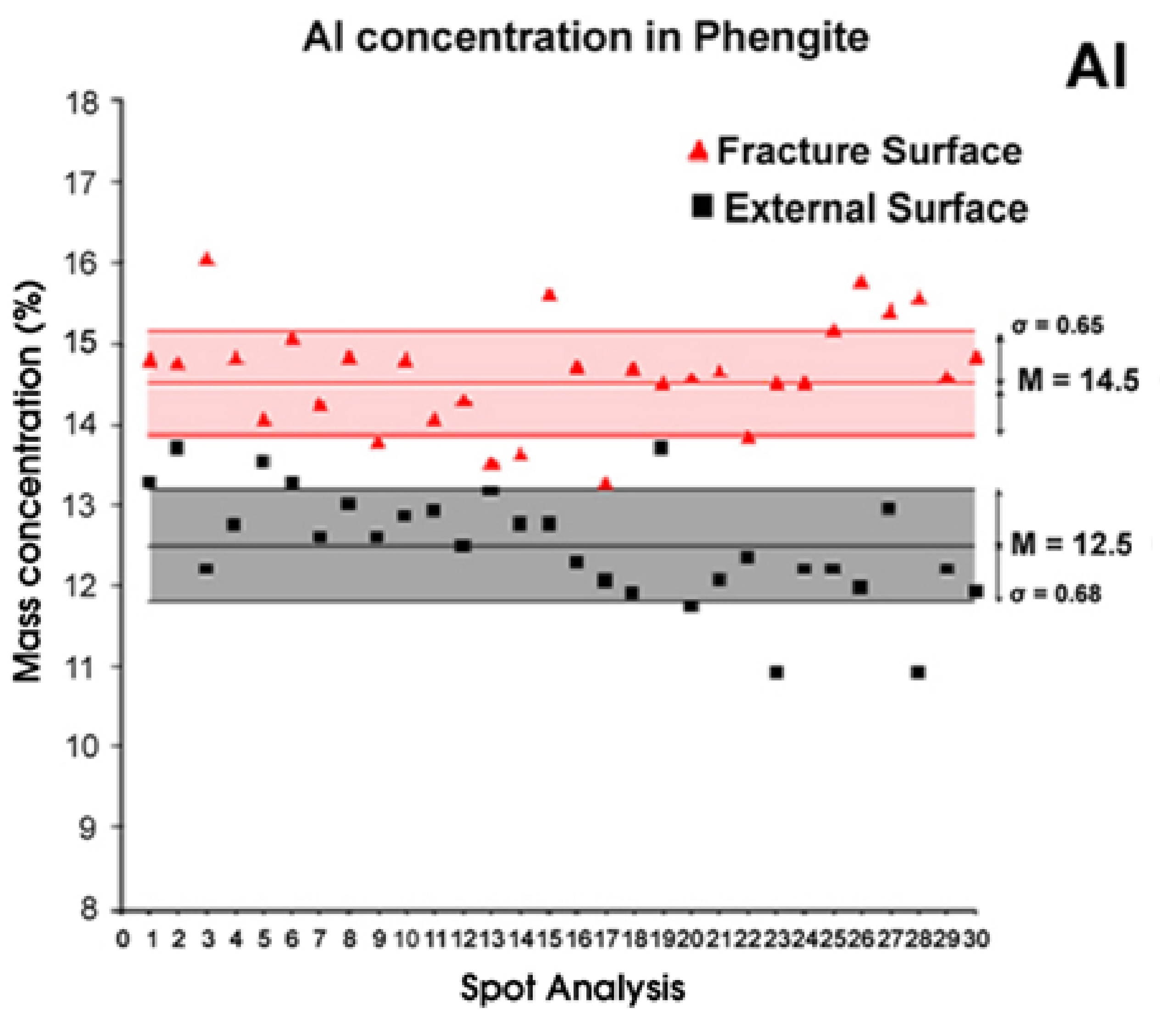
Fracture Surf.:

Fe content = 4.0%

Fe content decrease

–2.2%

Phengite (Granite) : Al concentrations



Fracture Surf.:

Al content = <u>14.5%</u>

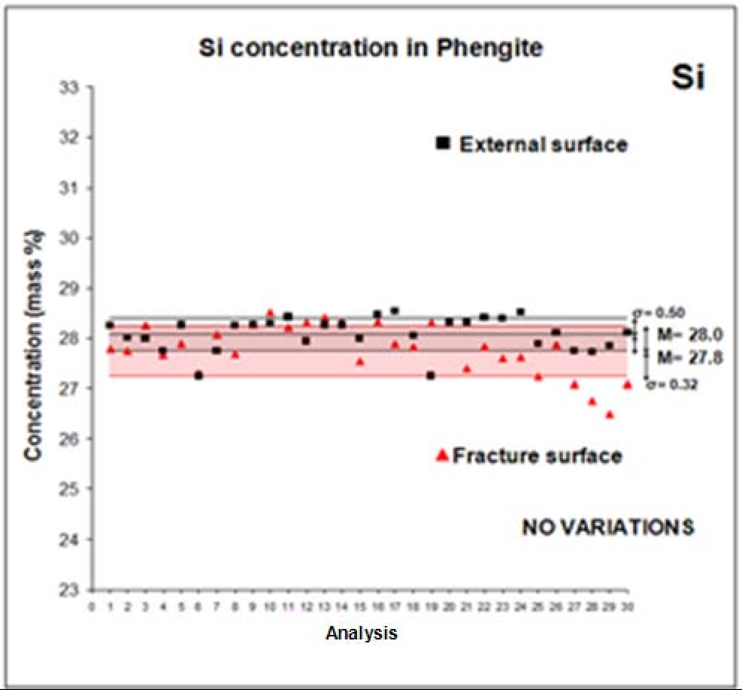
External Surf.:

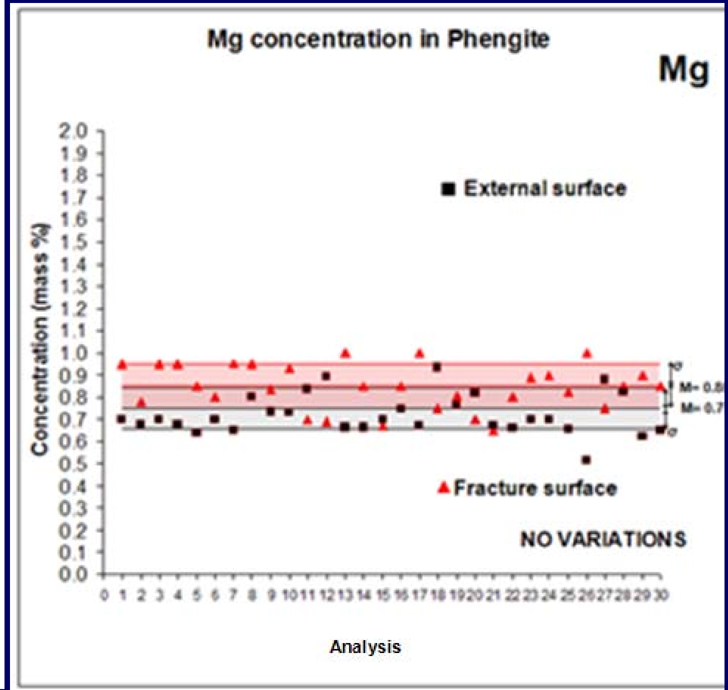
Al content = <u>12.5%</u>

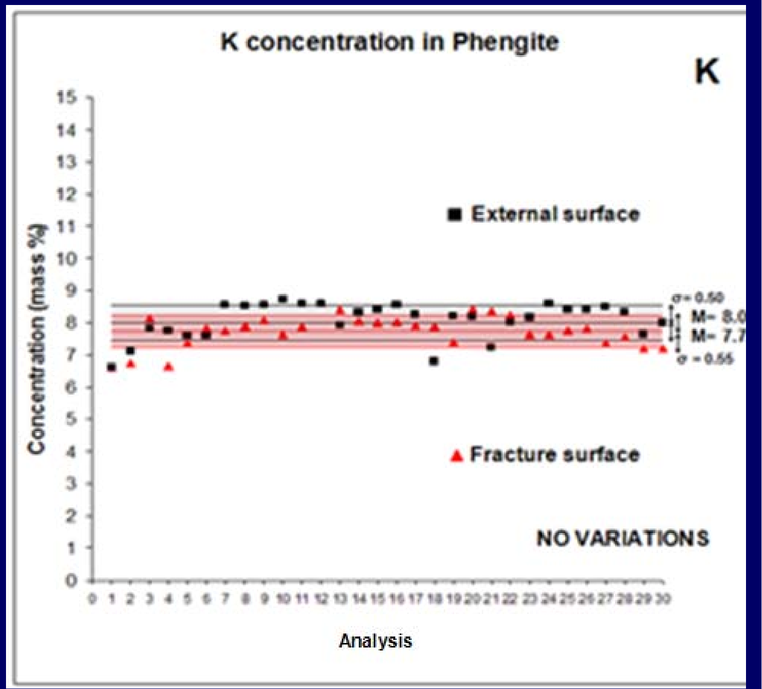
Al content increase

+2.0%

Phengite (Granite) : Si, Mg and K concentrations







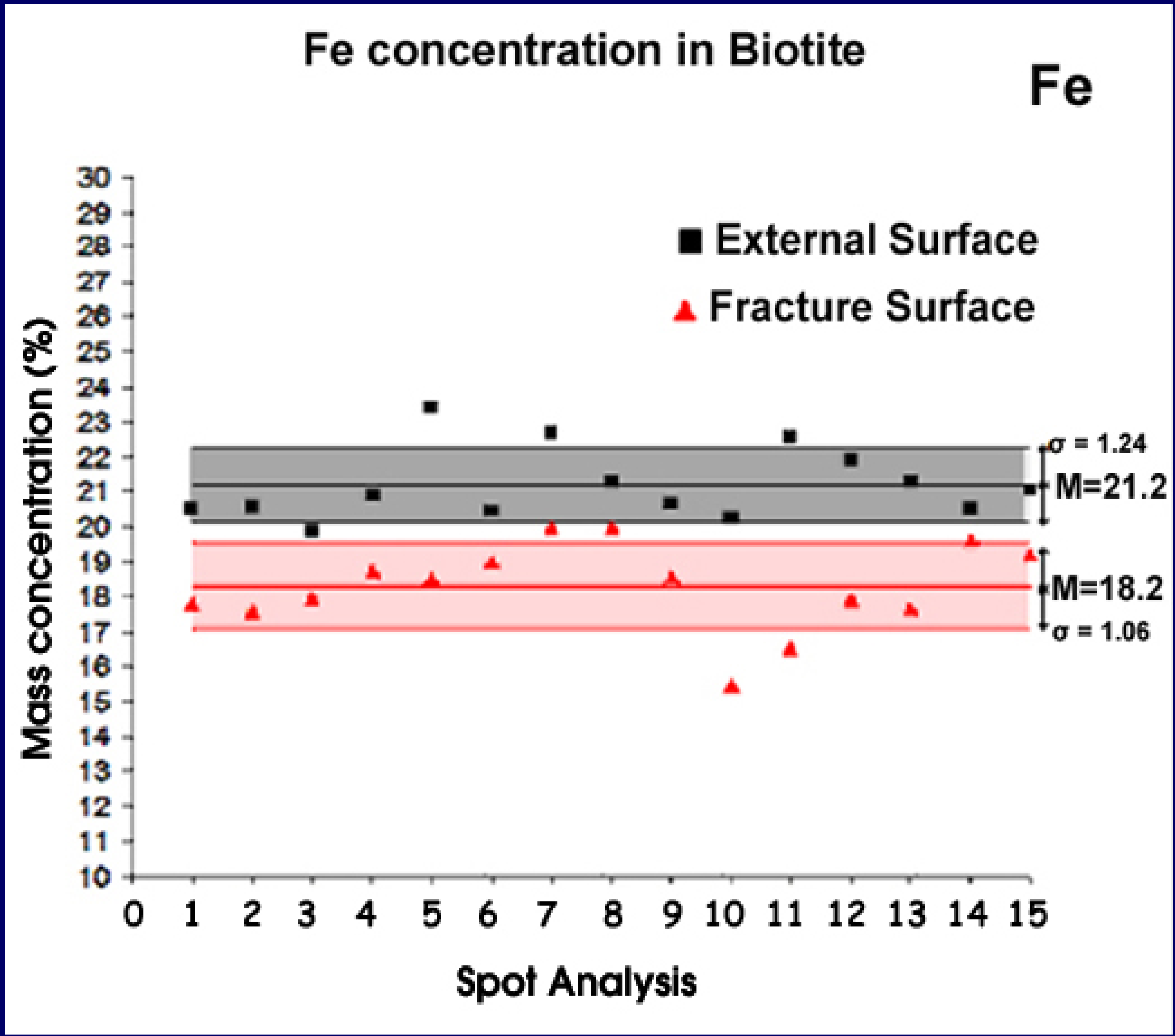
No appreciable variations can be recognized between the average values

Phengite (Granite)

	External surface mean value (wt%)	Fracture surface mean value (wt%)	Increase/ decrease with respect to phengite	Increase/ decrease with respect to the same element
Fe	6.2	4.0	–2.2%	–35%
Al	12.5	14.5	+2.0%	+16%
Si	28.0	27.8	NO VARIATIONS	NO VARIATIONS
Mg	0.7	0.8	NO VARIATIONS	NO VARIATIONS
K	8.0	7.7	NO VARIATIONS	NO VARIATIONS

$$Fe_{26}^{56} \rightarrow 2\,Al_{13}^{27} + 2\,n$$

Biotite (Granite): Fe concentrations



External Surf.:

Fe content = 21.2%

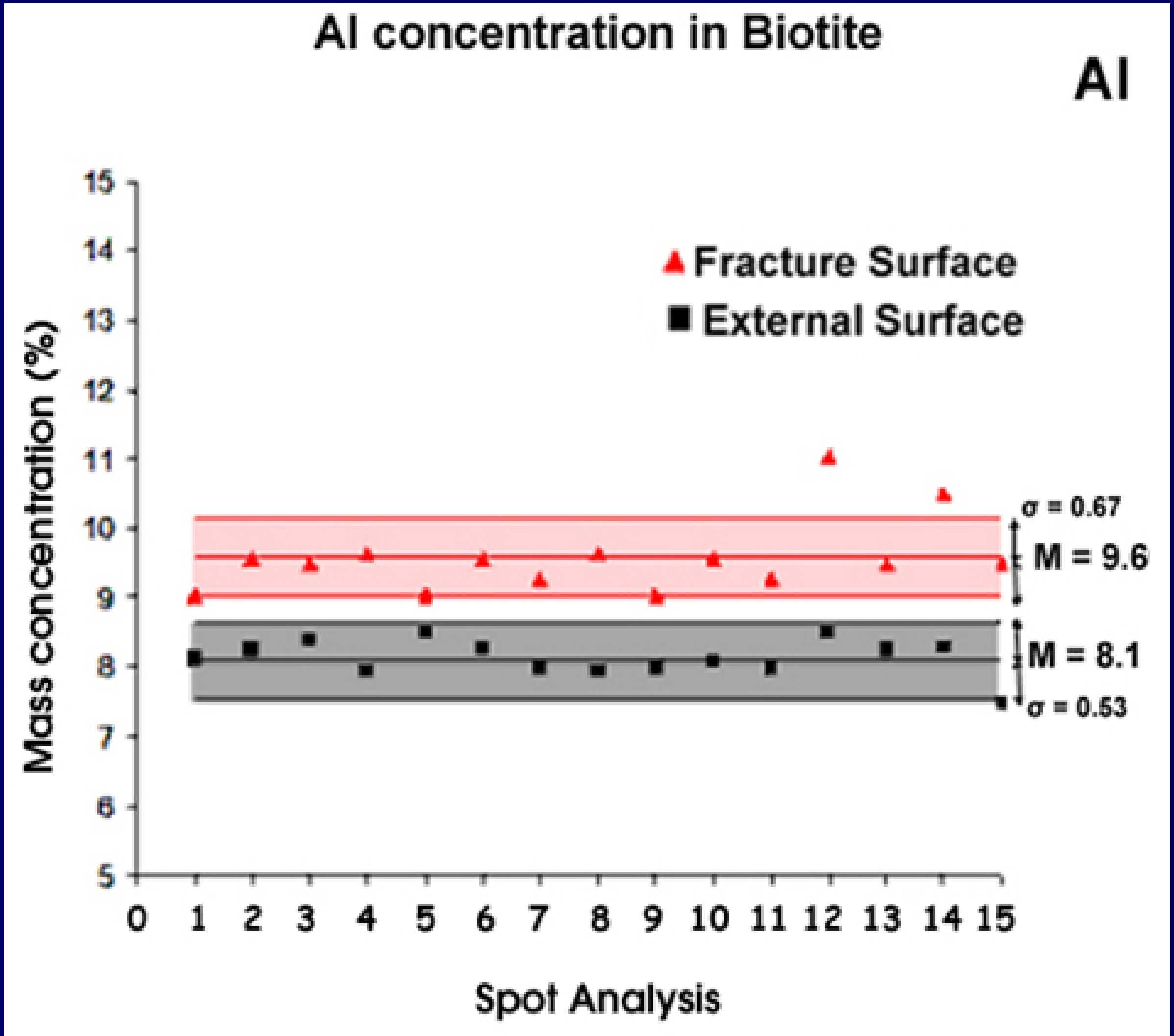
Fracture Surf.:

Fe content = 18.2%

Fe content decrease

–3.0%

Biotite (Granite) : Al concentrations



Fracture Surf.:

Al content = 9.6%

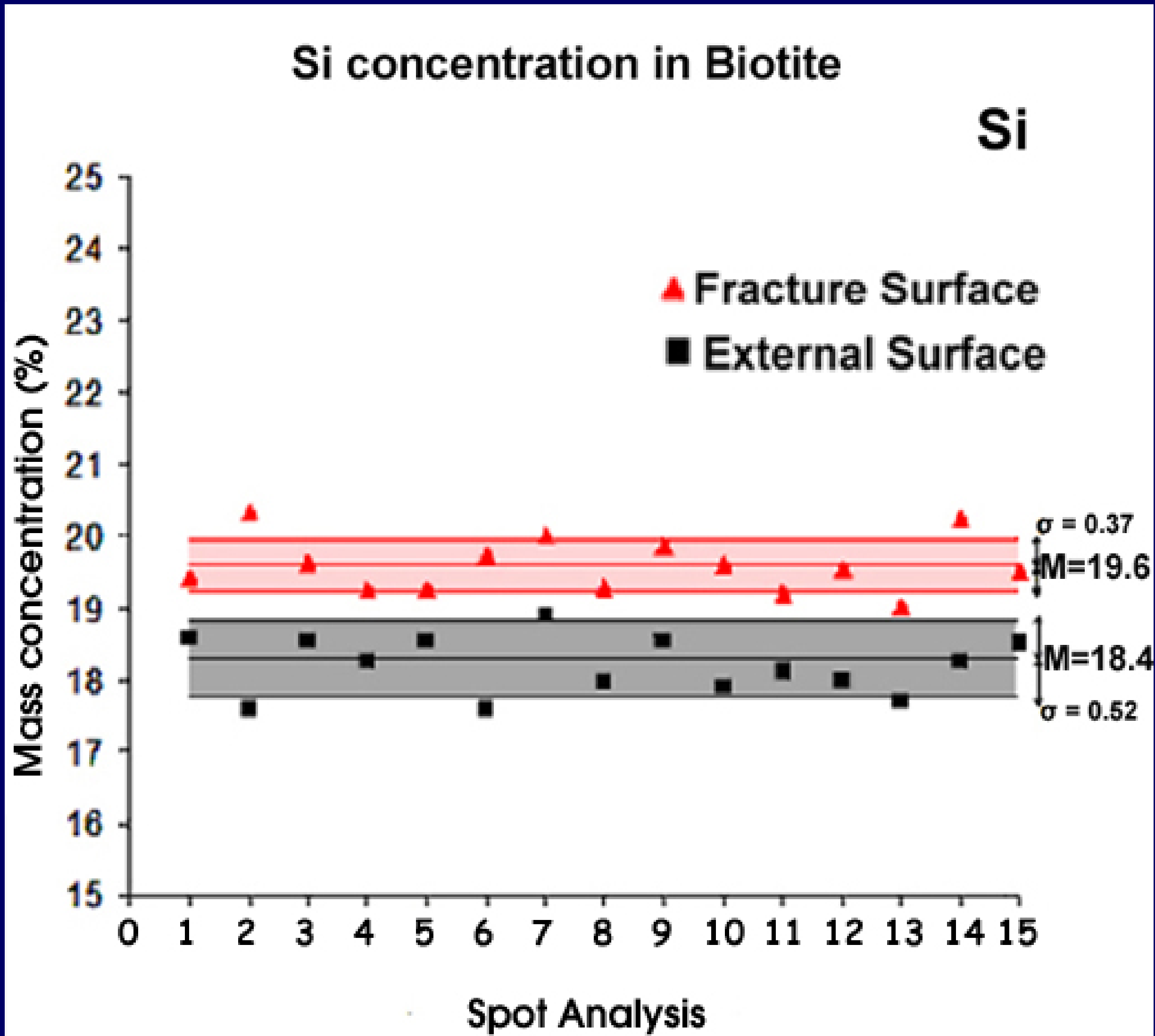
External Surf.:

Al content = 8.1%

Al content increase

+1.5%

Biotite (Granite) : Si concentrations



Fracture Surf.:

Si content = 19.6%

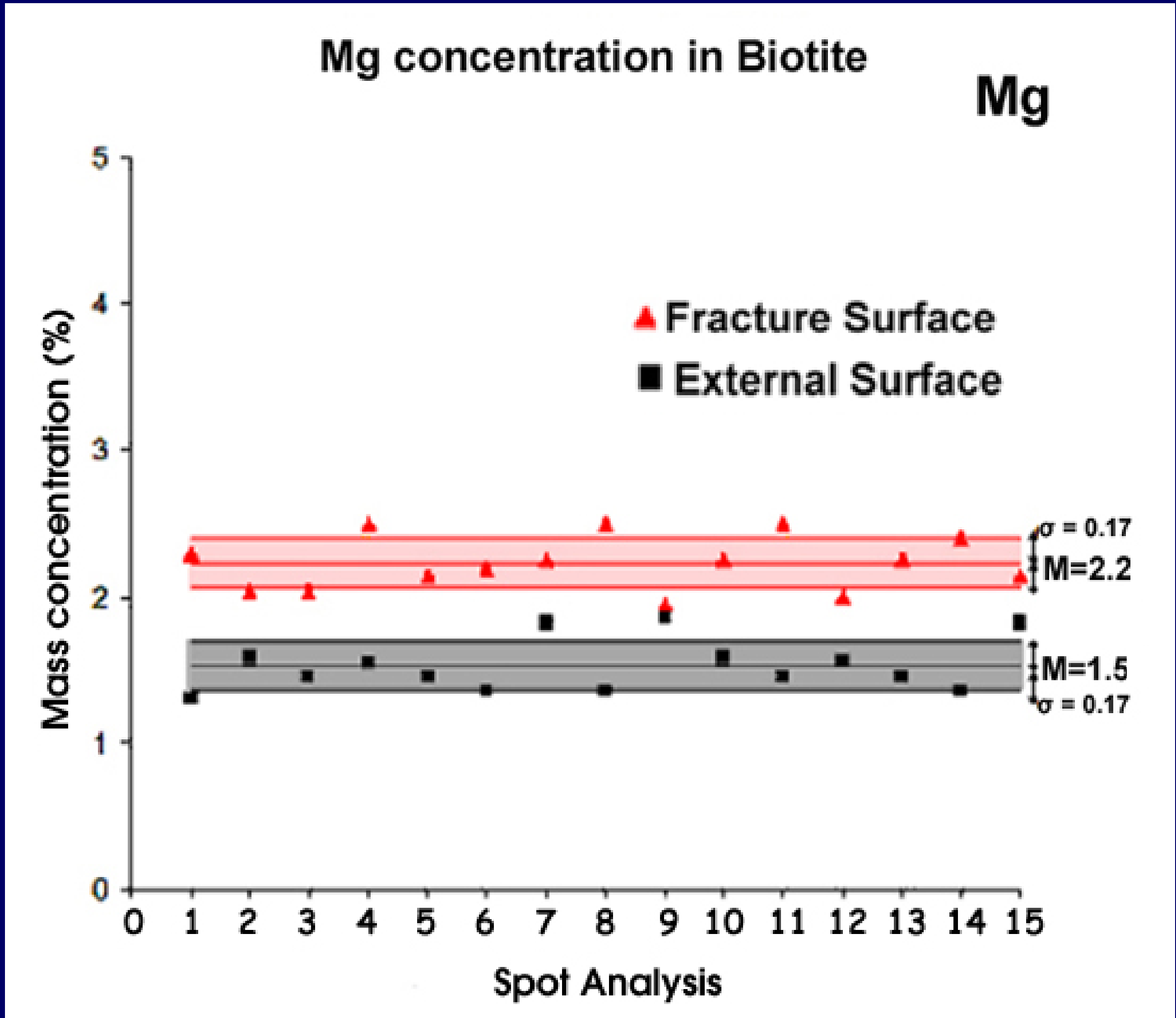
External Surf.:

Si content = 18.4%

Si content increase

+1.2%

Biotite (Granite) : Mg concentrations



Fracture Surf.:

Mg content = 2.2%

External Surf.:

Mg content = 1.5%

Mg content increase

+0.7%

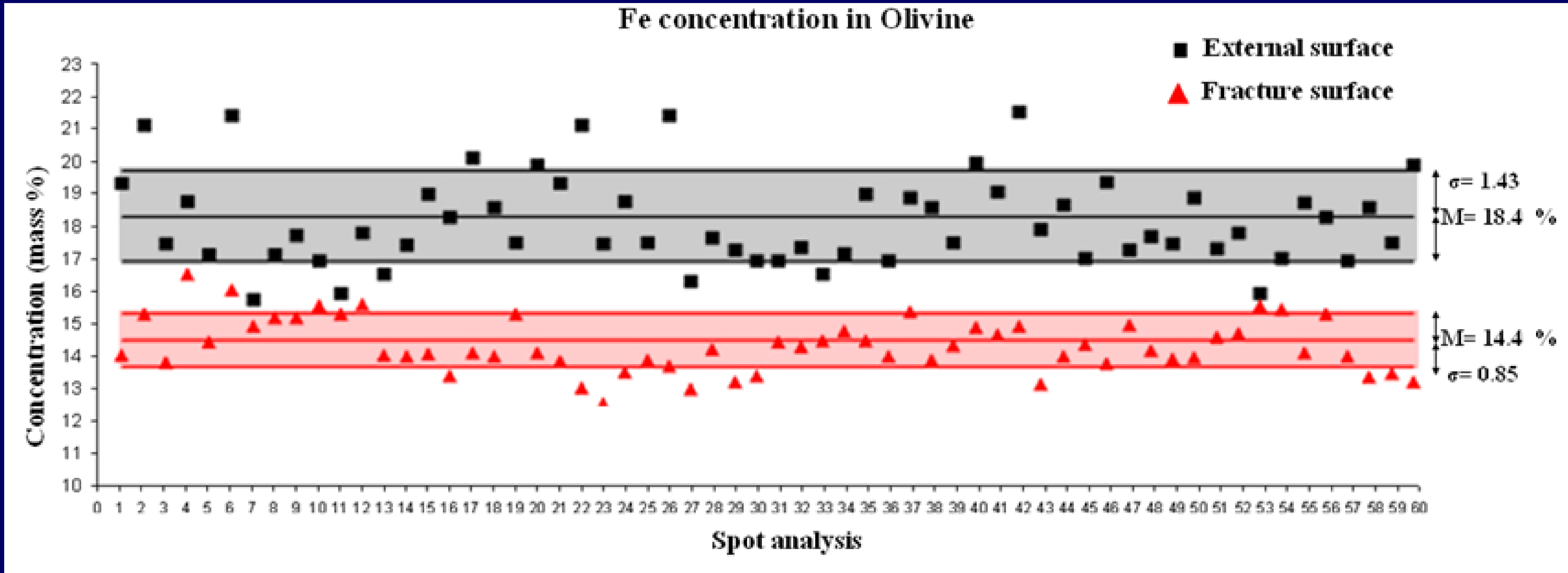
Biotite (Granite)

	External surface mean value (wt%)	Fracture surface mean value (wt%)	Increase/ decrease with respect to biotite	Increase/ decrease with respect to the same element
Fe	21.2	18.2	–3.0 %	–14%
Al	8.1	9.6	+1.5 %	+18%
Si	18.4	19.6	+1.2 %	+6%
Mg	1.5	2.2	+0.7 %	+46%
K	6.9	7.1	NO VARIATIONS	NO VARIATIONS

$$Fe_{26}^{56} \rightarrow 2\,Al_{13}^{27} + 2n$$

$$Fe_{26}^{56} \rightarrow Si_{14}^{28} + Mg_{12}^{24} + 4n$$

Olivine (Basalt): Fe concentrations



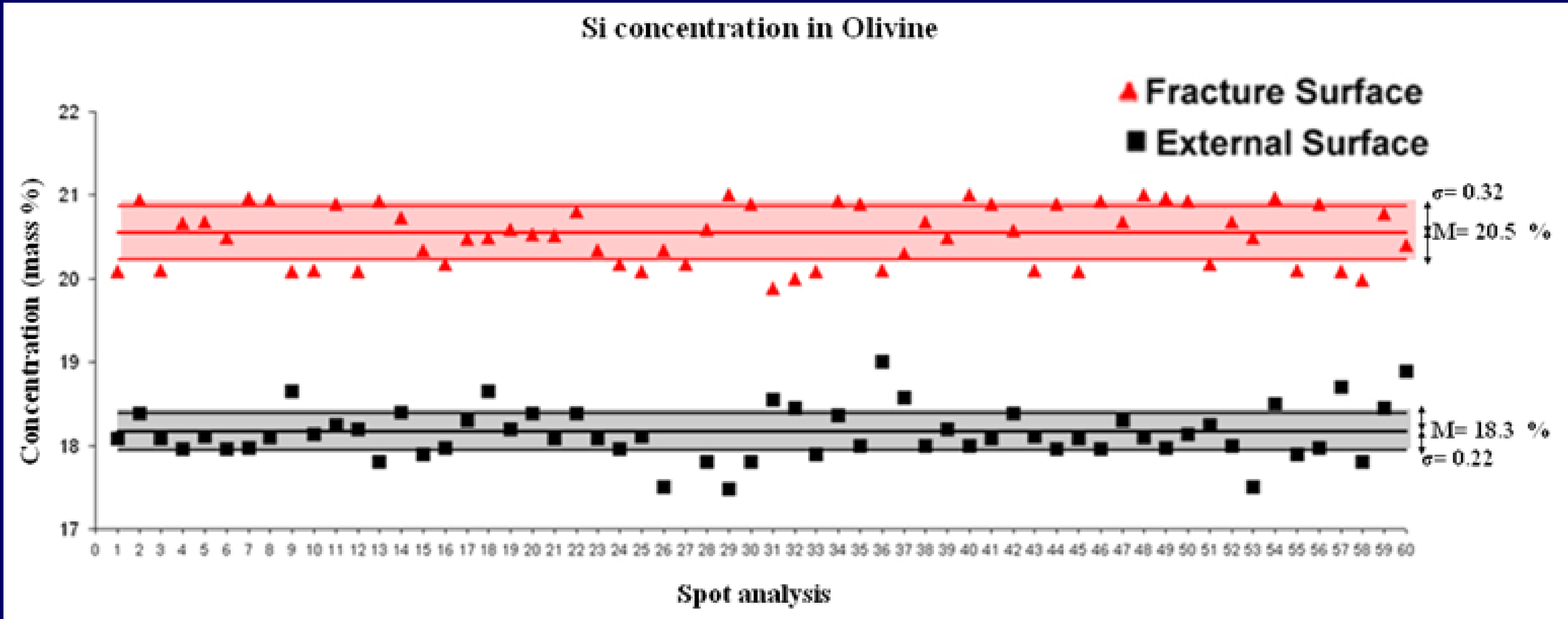
External Surf.: Fe content = 18.4%

Fracture Surf.: Fe content = 14.4%

Fe content decrease

– 4.0%

Basalt (Olivine): Si concentrations



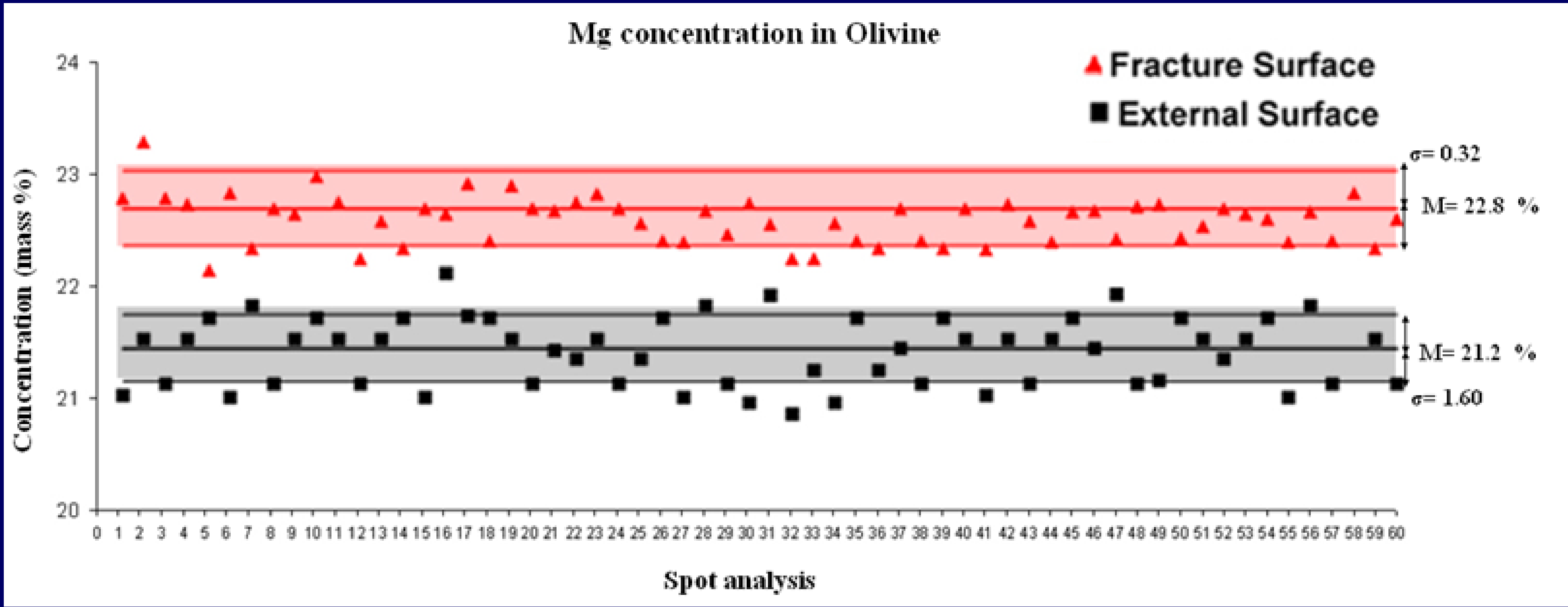
Fracture Surf.: Fe content = 20.5%

External Surf.: Fe content = 18.3%

Si content increase

+ 2.2%

Basalt (Olivine): Mg concentrations



Fracture Surf.: Fe content = 22.8%

External Surf.: Fe content = 21.2%

Si content increase

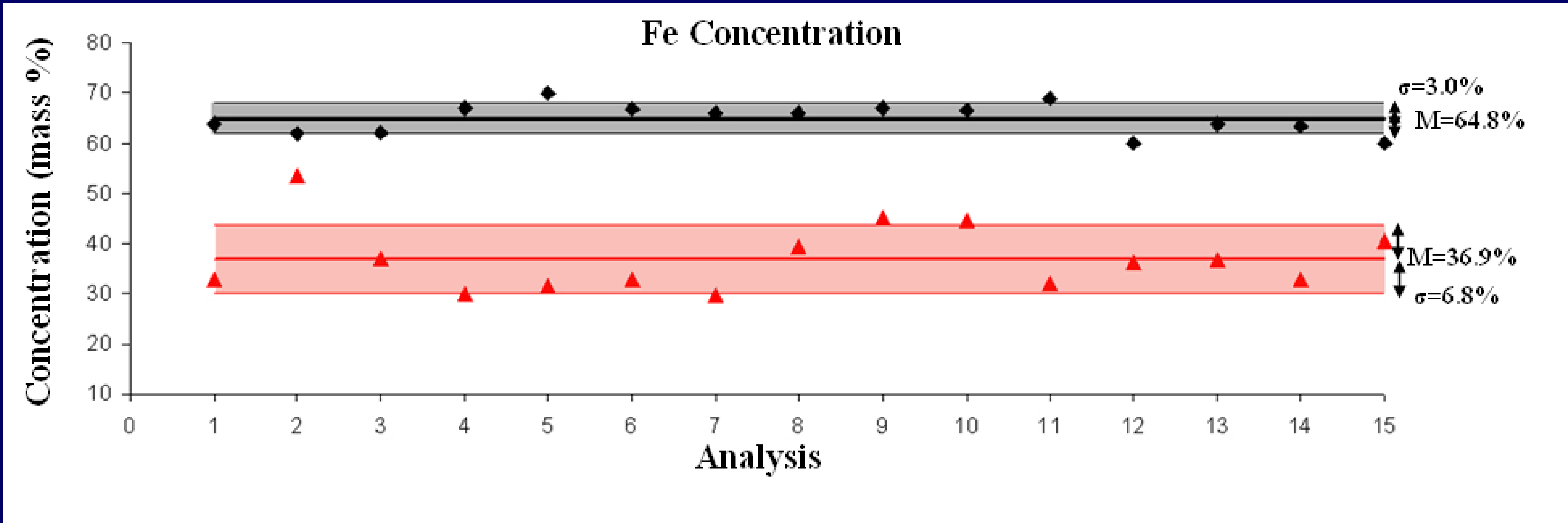
+ 1.6%

Olivine (Basalt)

	External surface mean value (wt%)	Fracture surface mean value (wt%)	Increase/decrease with respect to Olivine	Increase/decrease with respect to the same element
Fe	18.4	14.4	–4.0%	–21%
Si	18.3	20.5	+2.2%	+12%
Mg	21.2	22.8	+1.6%	+7%
Ca	0.5	0.5	NO VARIATIONS	NO VARIATIONS

$$Fe^{56}_{26} \rightarrow Si^{28}_{14} + Mg^{24}_{12} + 4n$$

Magnetite: Fe concentrations



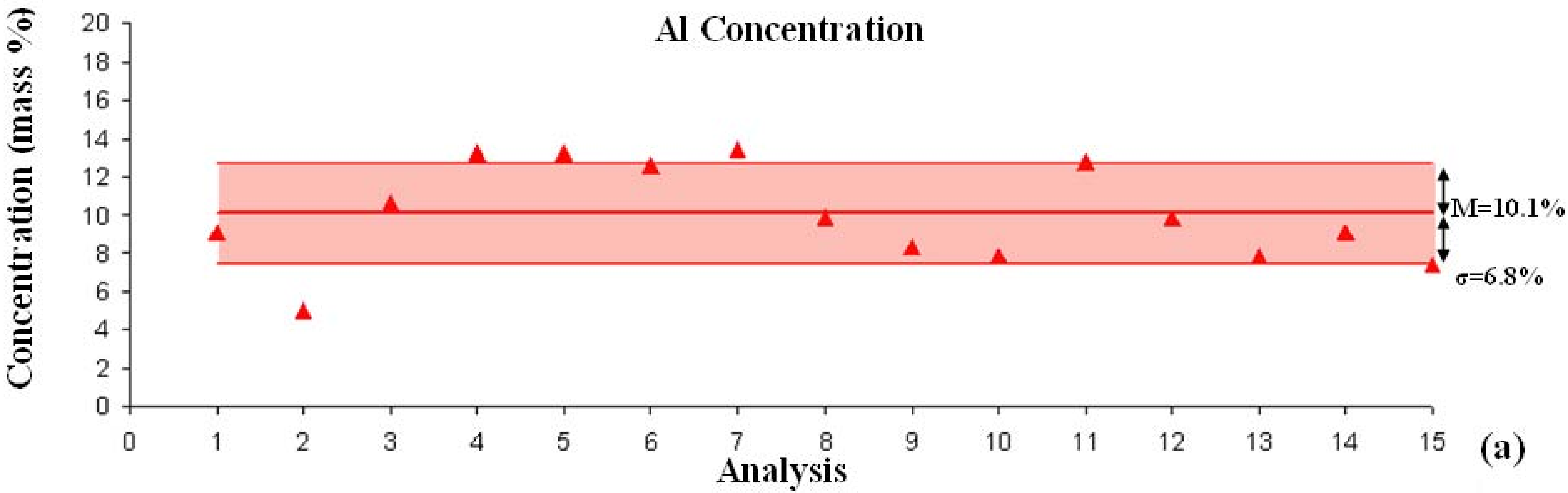
External Surf.: Fe content = 64.8%

Fracture Surf.: Fe content = 36.9%

Fe content decrease

– 27.9%

Magnetite: Al concentration



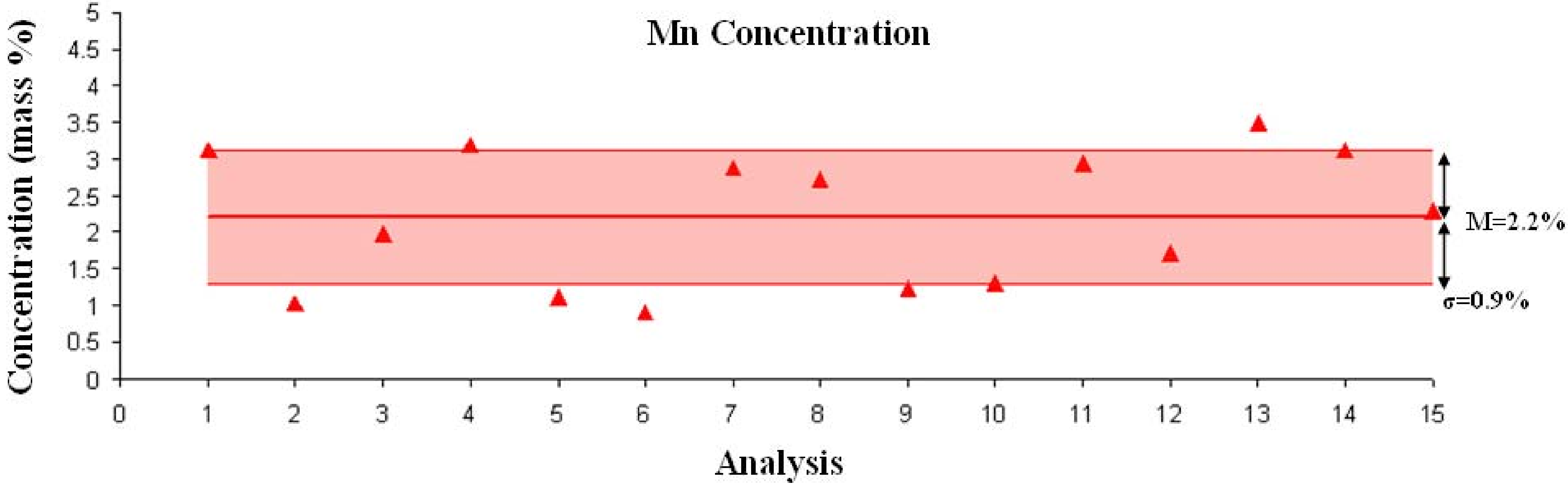
Fracture Surf.: Al content = 10.1%

External Surf.: Al content = ~0.0%

Al content increase

+ 10.1%

Magnetite: Mn concentration



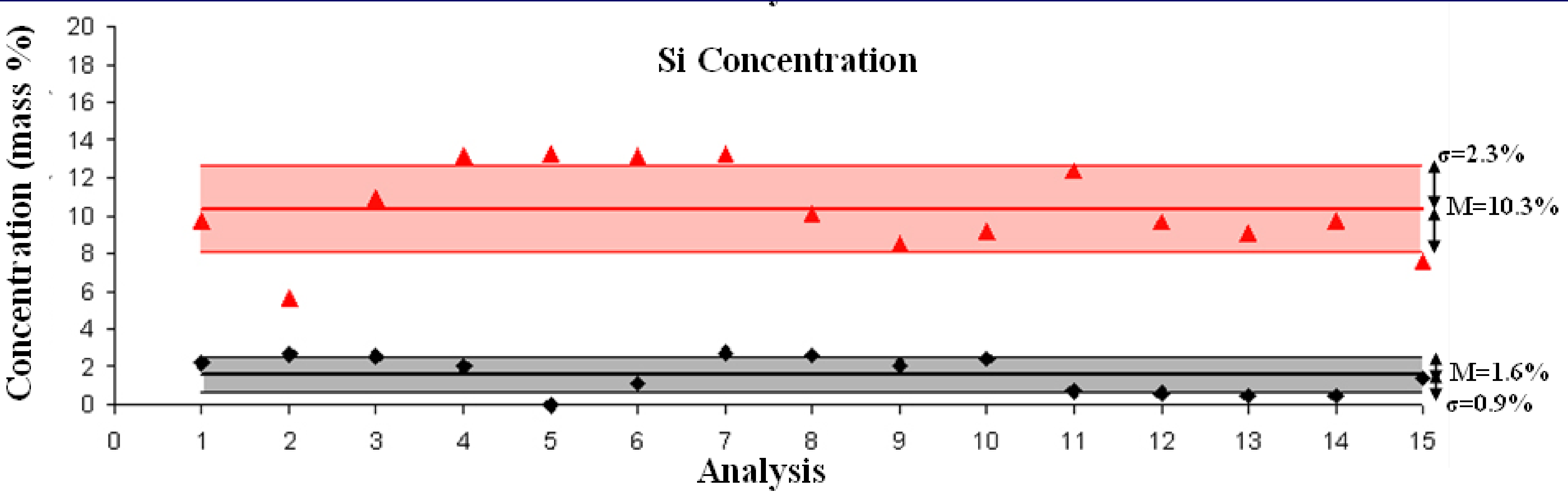
Fracture Surf.: Mn content = 2.2%

External Surf.: Mn content = 0.0%

Mn content increase

+ 2.2%

Magnetite: Si concentration



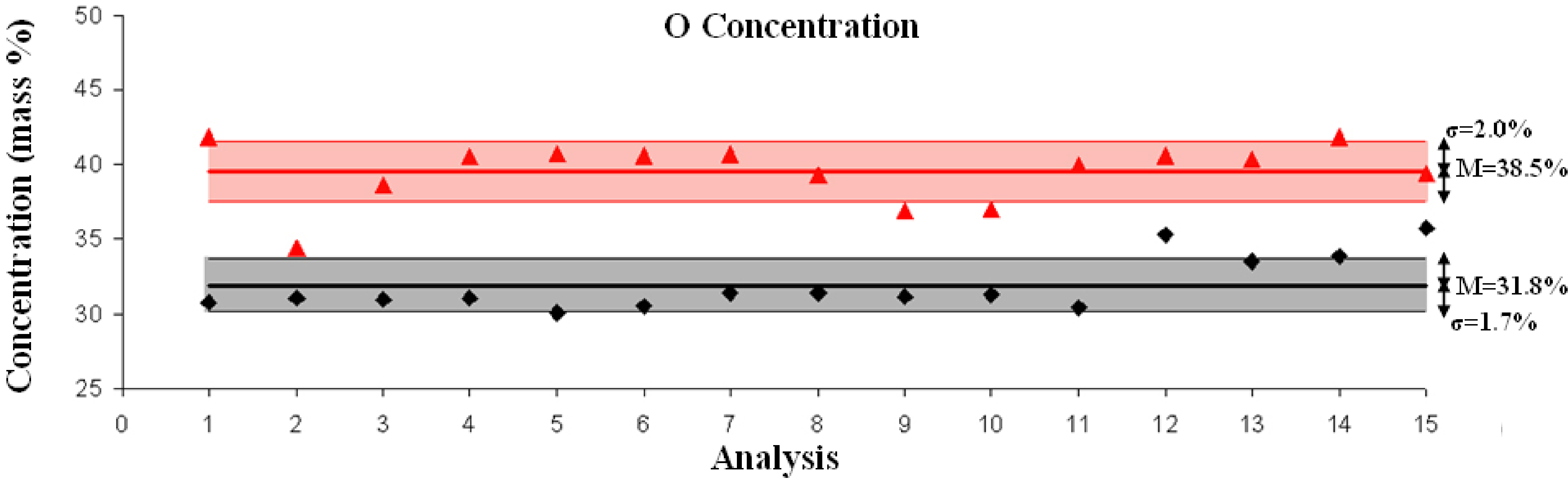
Fracture Surf.: Si content = 10.3%

External Surf.: Si content = 1.6%

Si content increase

+ 8.7%

Magnetite: O concentration



Fracture Surf.: Fe content = 38.5%

External Surf.: Fe content = 31.8%

O content increase

+ 6.7%

Magnetite

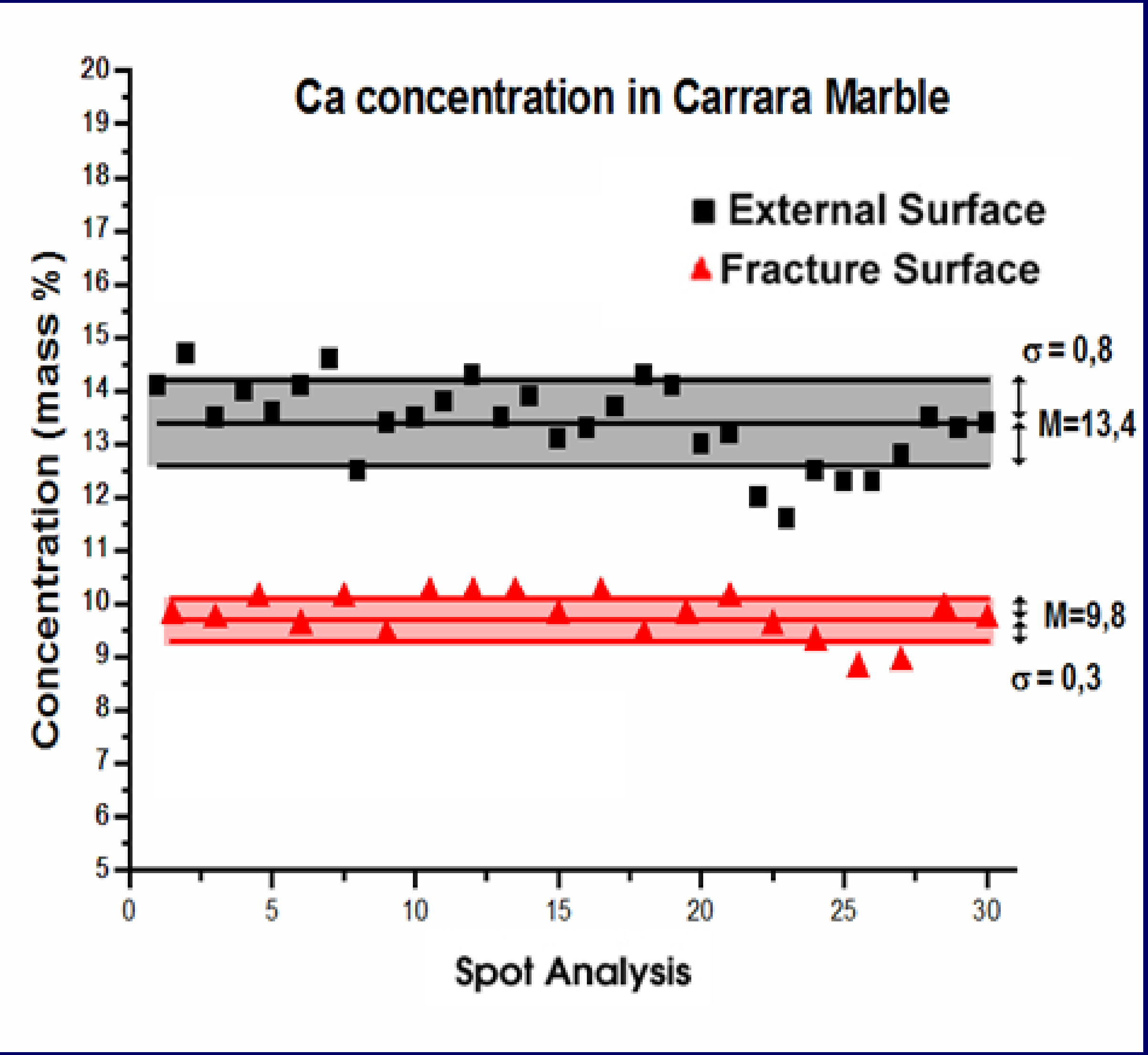
	External surface mean value (wt%)	Fracture surface mean value (wt%)	Increase/decrease with respect to Magnetite	Increase/decrease with respect to the same element
Fe	64.8	36.8	−27.9%	−56%
Al	–	10.1	+10.1%	BEFORE ABSENT
Mn	–	2.2	+2.2%	BEFORE ABSENT
Si	1.6	10.3	+8.7%	+540%
O	31.8	38.5	+6.7%	+21%

$$Fe_{26}^{56} \rightarrow 2\,Al_{13}^{27} + 2\,n$$

$$Fe_{26}^{56} \rightarrow Mn_{25}^{55} + H_{1}^{1}$$

$$Fe_{26}^{56} \rightarrow Si_{14}^{28} + O_{8}^{16} + 2He_{2}^{4} + 4n$$

Carrara Marble: Ca concentrations



External Surf.:

Ca content = <u>13.4%</u>

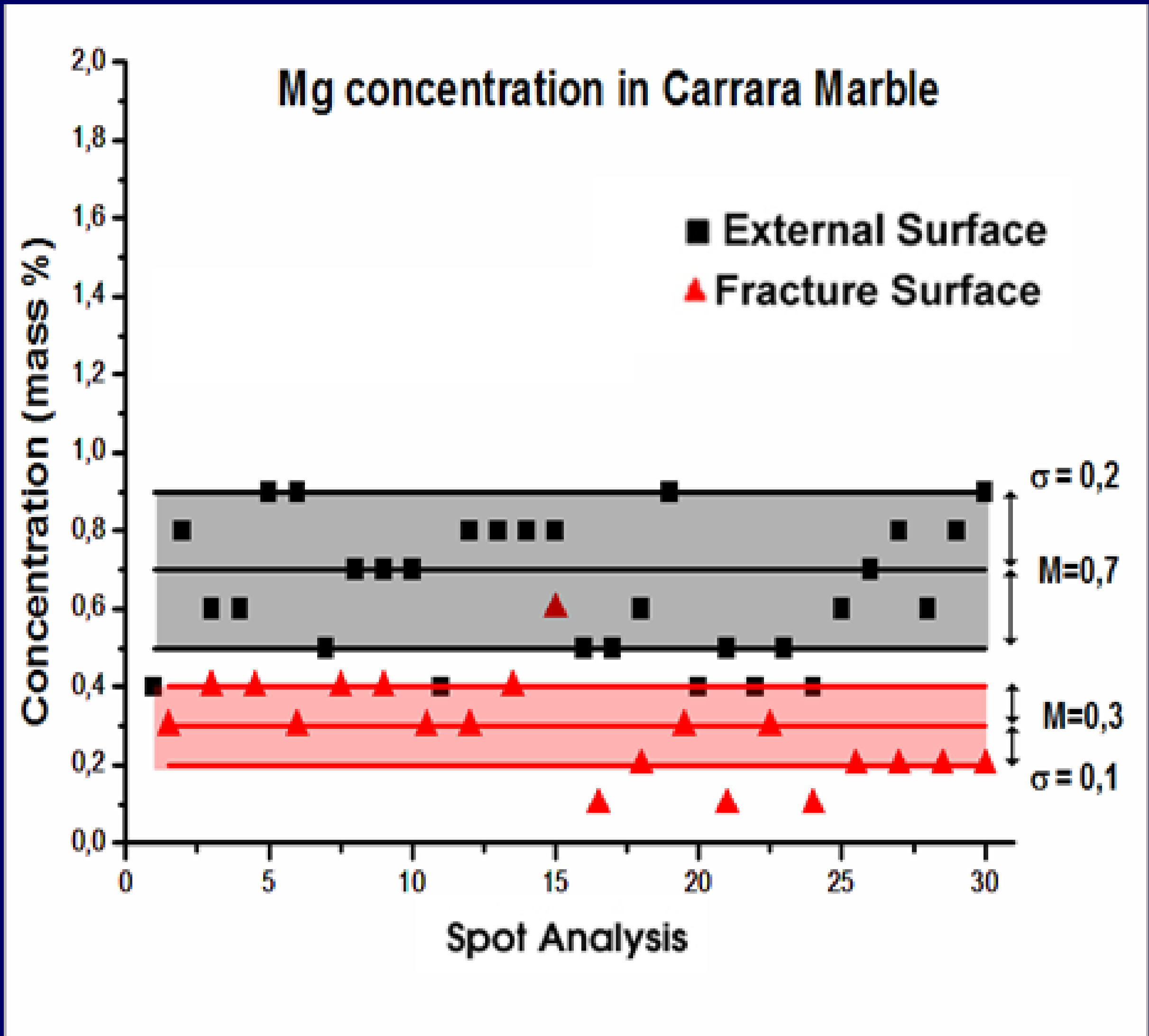
Fracture Surf.:

Ca content = <u>9.8%</u>

Ca content decrease

–3.6%

Carrara Marble: Mg concentrations



External Surf.:

Mg content = <u>0.7%</u>

Fracture Surf.:

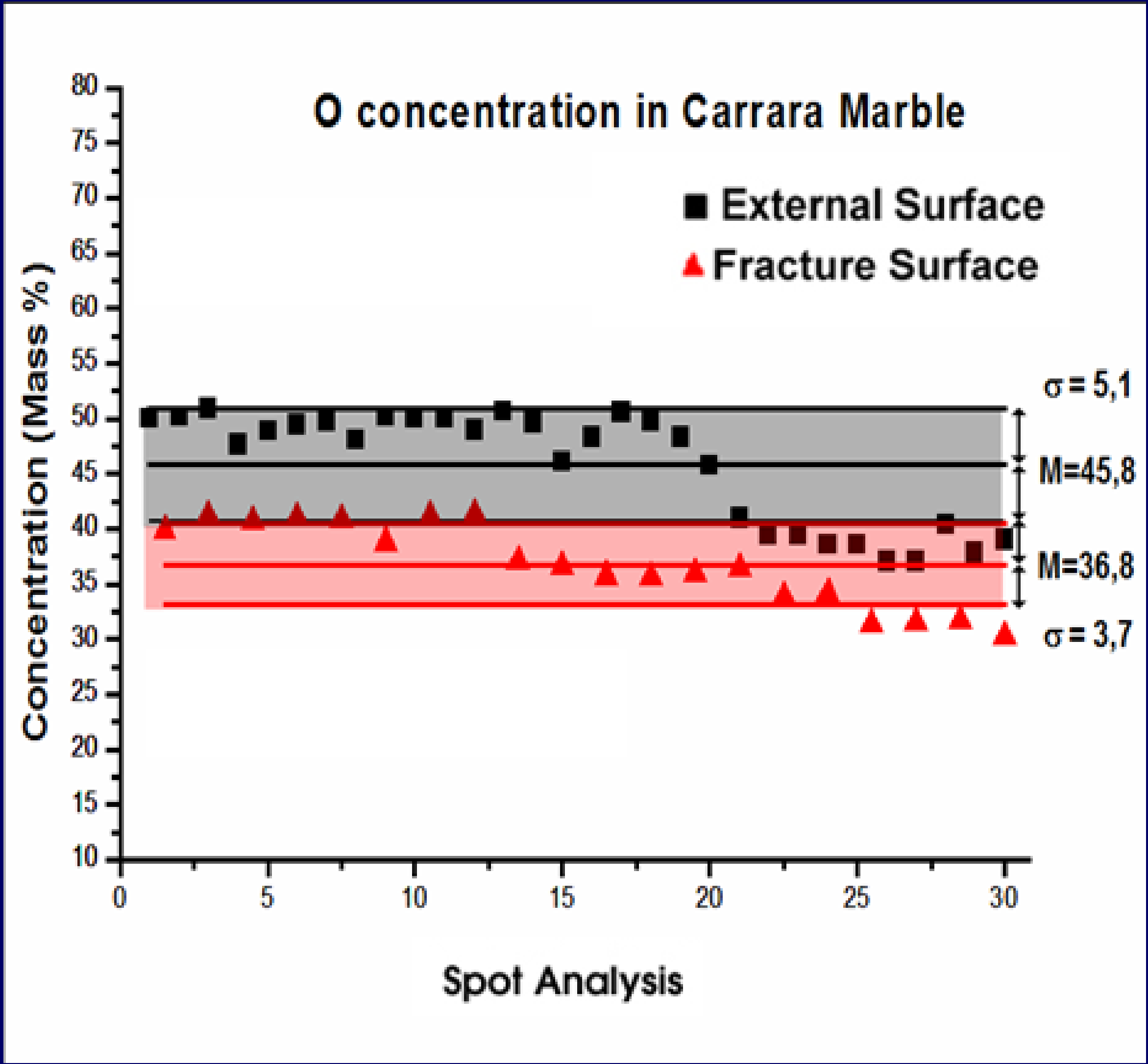
Mg content = <u>0.3%</u>

Mg content decrease

–0.4%

Carrara Marble: O concentrations

X-ray Photoelectron Spectroscopy



External Surf.:

O content = <u>45.8%</u>

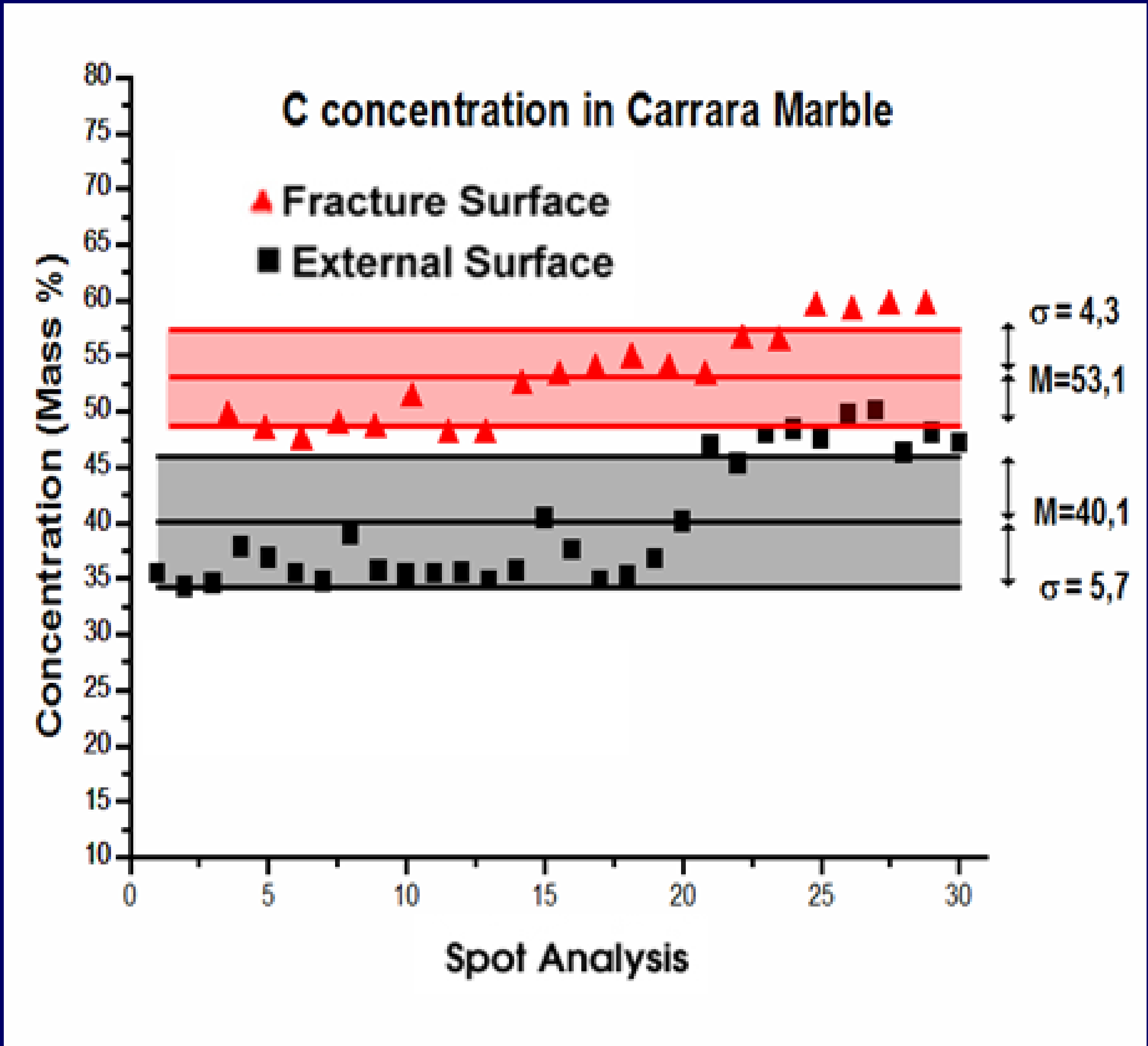
Fracture Surf.:

O content = <u>36.8%</u>

O content decrease

–9.0%

Carrara Marble: C concentrations



Fracture Surf.:

C content = <u>53.1%</u>

External Surf.:

C content = <u>40.1%</u>

C content increase

+13.0%

Carrara Marble

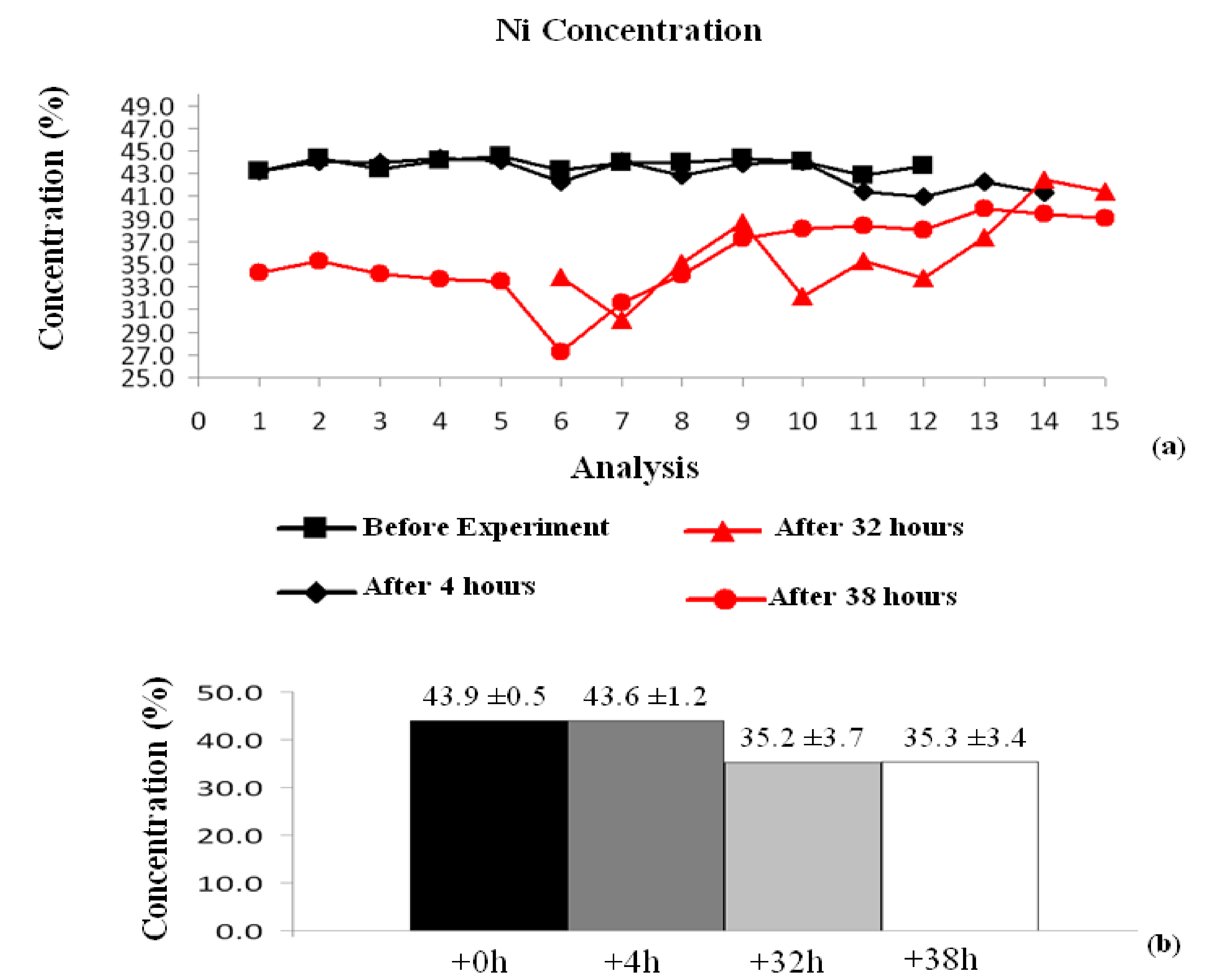
	External surface mean value (wt%)	Fracture surface mean value (wt%)	Increase/ decrease with respect to Carrara Marble	Increase/ decrease with respect to the same element
Ca	13.4	9.8	–3.6 %	–26%
Mg	0.7	0.3	–0.4 %	–57%
O	45.8	36.8	–9.0 %	–19%
C	40.1	53.1	+13.0%	+32%

$$Ca_{20}^{40} \rightarrow 3C_{6}^{12} + He_{2}^{4}$$

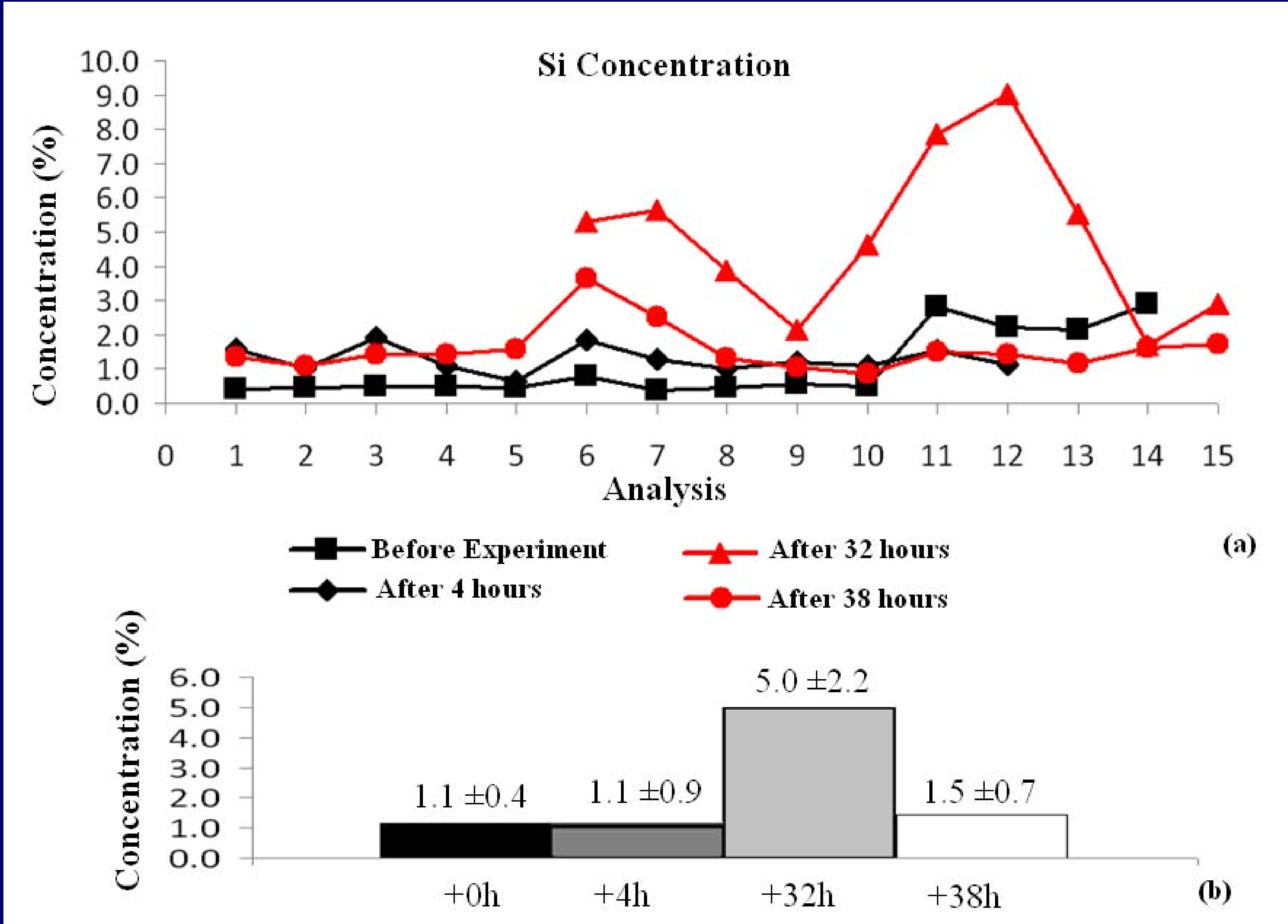
$$Mg_{12}^{24} \rightarrow 2C_{6}^{12}$$

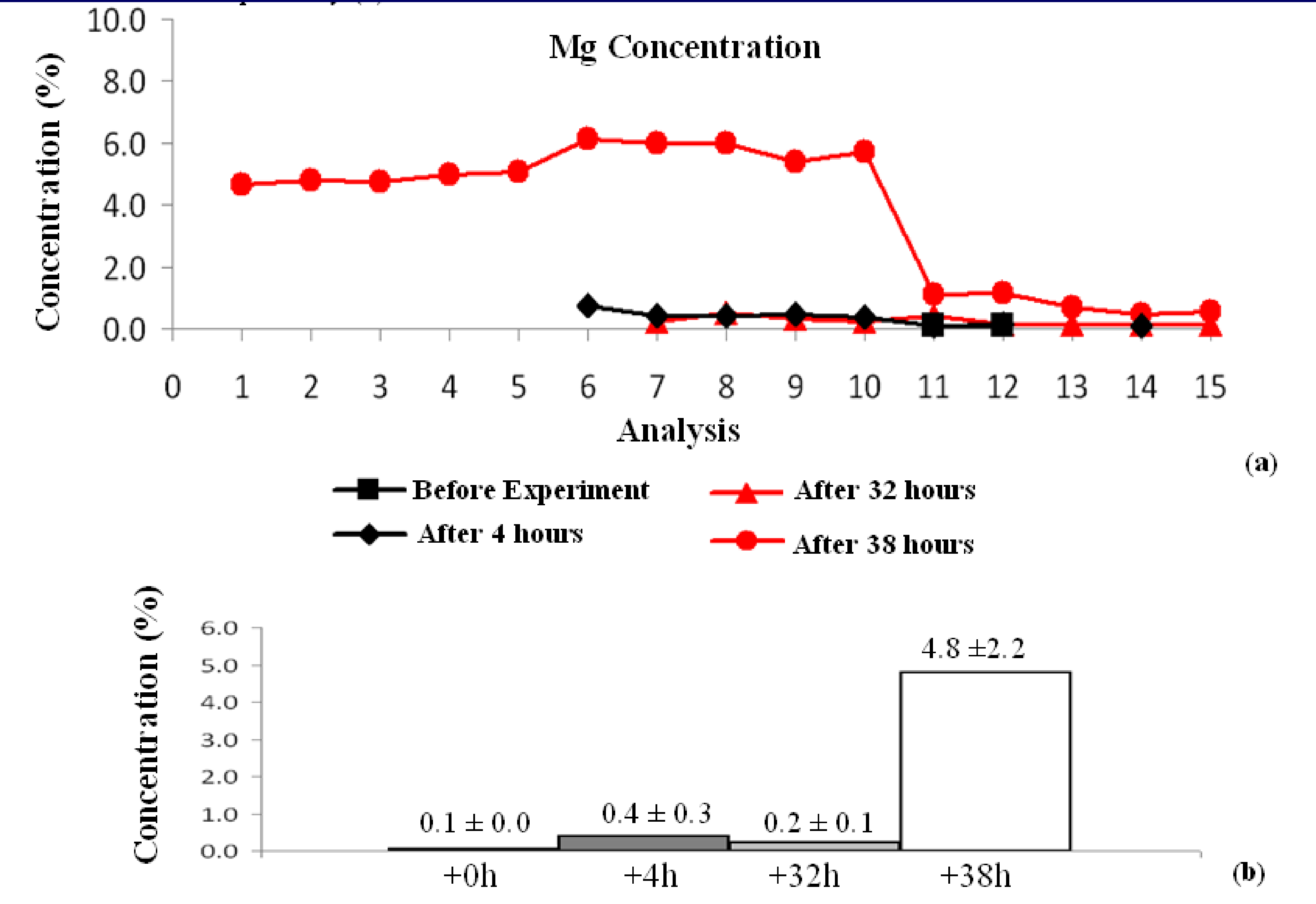
$$O_{8}^{16} \rightarrow C_{6}^{12} + He_{2}^{4}$$

APPENDIX B

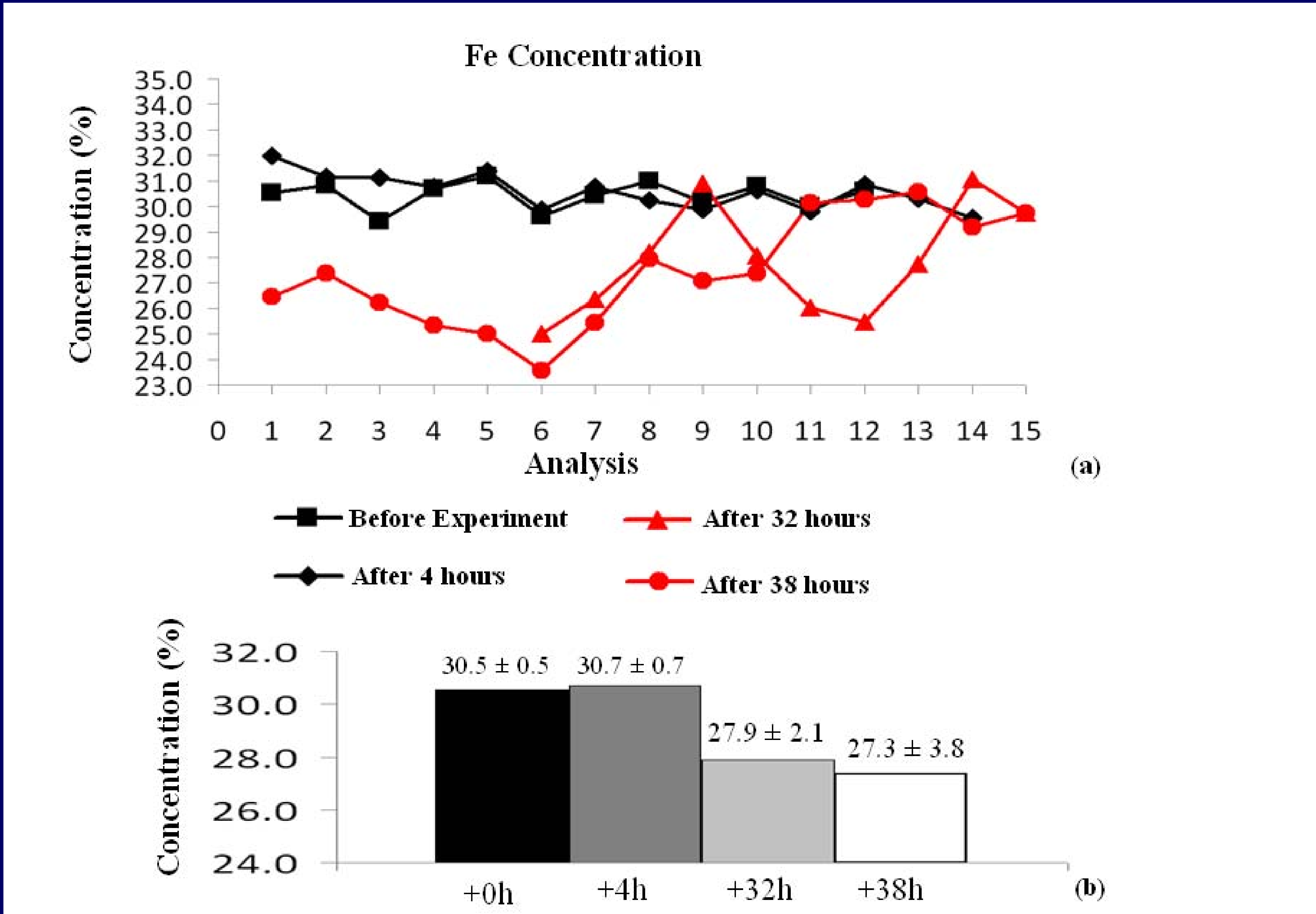


Ni Concentration
Concentration (%)
49.0
47.0
45.0
43.0
41.0
39.0
37.0
35.0
33.0
31.0
29.0
27.0
25.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
(a)
Analysis
Before Experiment
After 32 hours
After 4 hours
After 38 hours
Concentration (%)
50.0
40.0
30.0
20.0
10.0
0.0
43.9 ±0.5
43.6 ±1.2
35.2 ±3.7
35.3 ±3.4
+0h
+4h
+32h
+38h
(b)

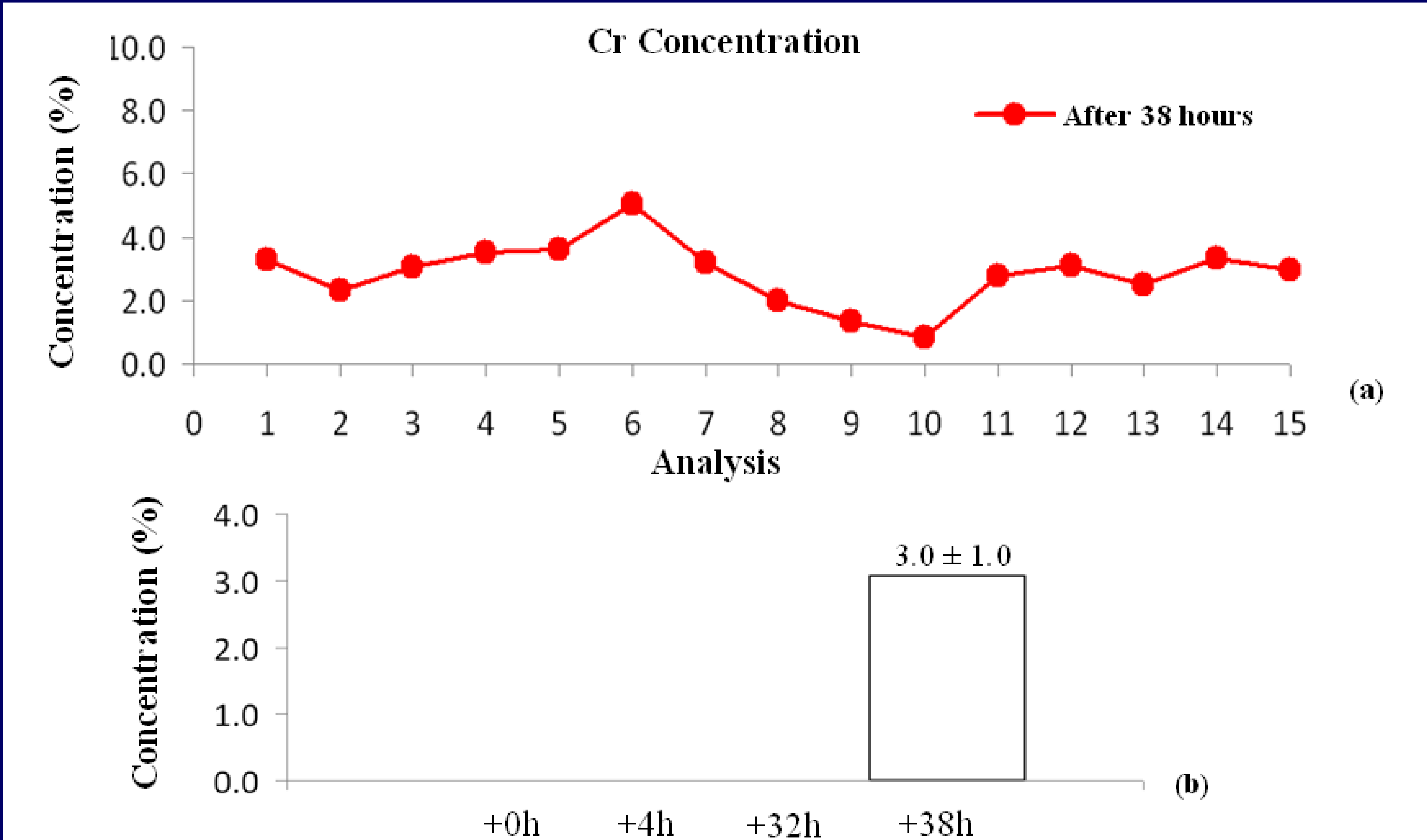

Si Concentration
Concentration (%)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Analysis
Before Experiment
After 4 hours
After 32 hours
After 38 hours
(a)
Concentration (%)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1.1 ±0.4
1.1 ±0.9
5.0 ±2.2
1.5 ±0.7
+0h
+4h
+32h
+38h
(b)



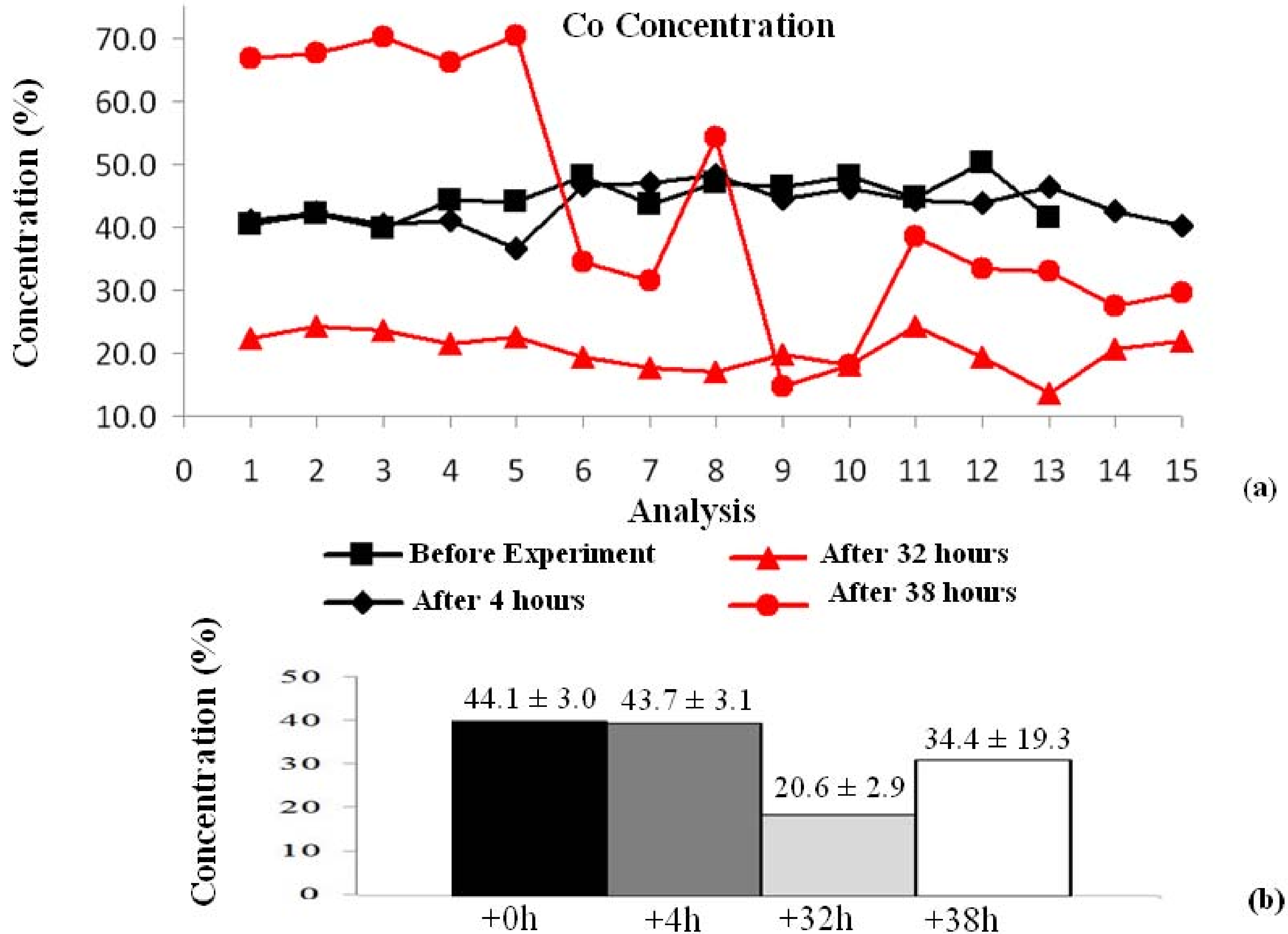
Mg Concentration
Concentration (%)
10.0
8.0
6.0
4.0
2.0
0.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Analysis
(a)
Before Experiment
After 4 hours
After 32 hours
After 38 hours
Concentration (%)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.1 ± 0.0
0.4 ± 0.3
0.2 ± 0.1
4.8 ±2.2
+0h
+4h
+32h
+38h
(b)



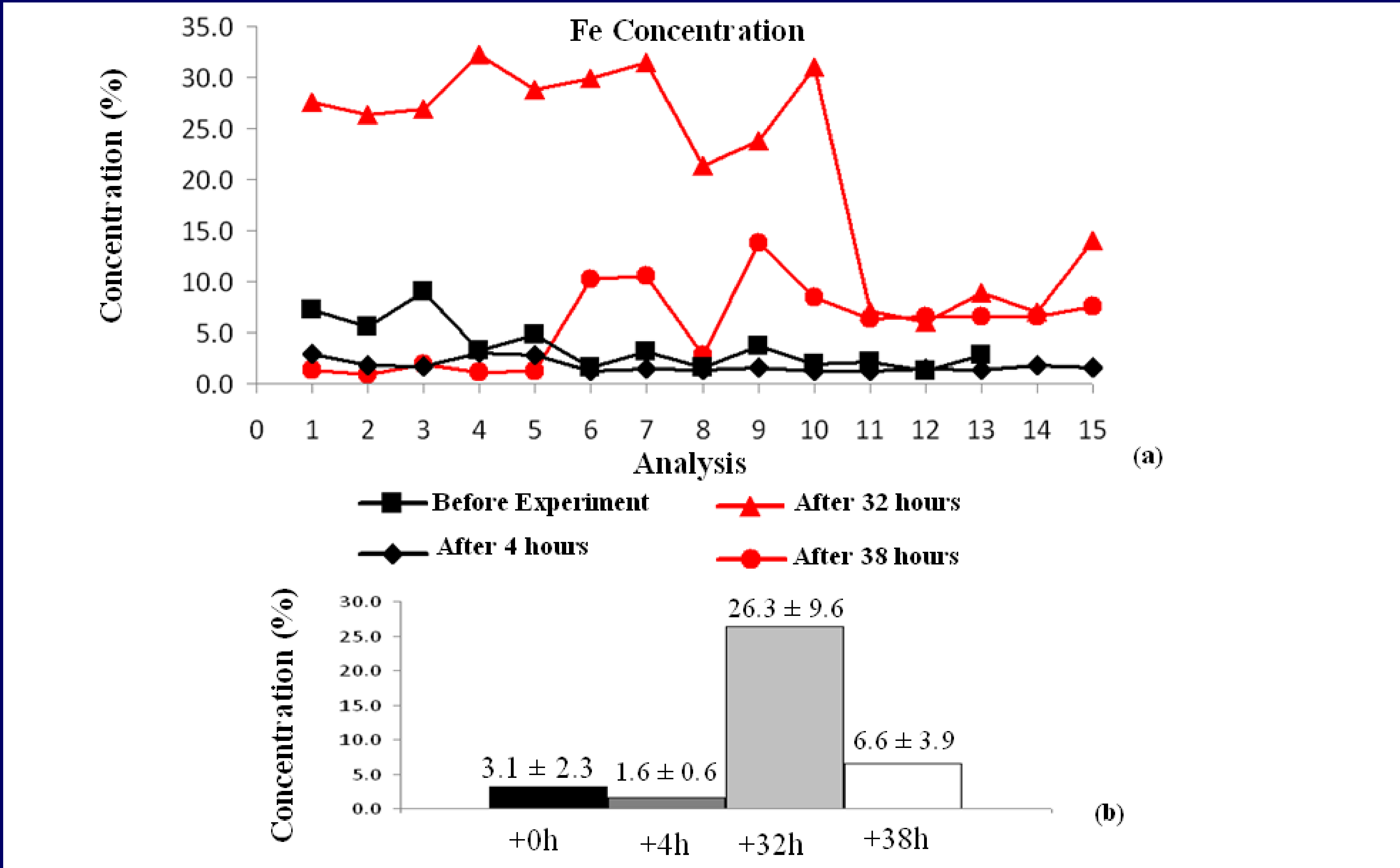
Fe Concentration
Concentration (%)
35.0
34.0
33.0
32.0
31.0
30.0
29.0
28.0
27.0
26.0
25.0
24.0
23.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Analysis
(a)
Before Experiment
After 32 hours
After 4 hours
After 38 hours
Concentration (%)
32.0
30.0
28.0
26.0
24.0
30.5 ± 0.5
30.7 ± 0.7
27.9 ± 2.1
27.3 ± 3.8
+0h
+4h
+32h
+38h
(b)



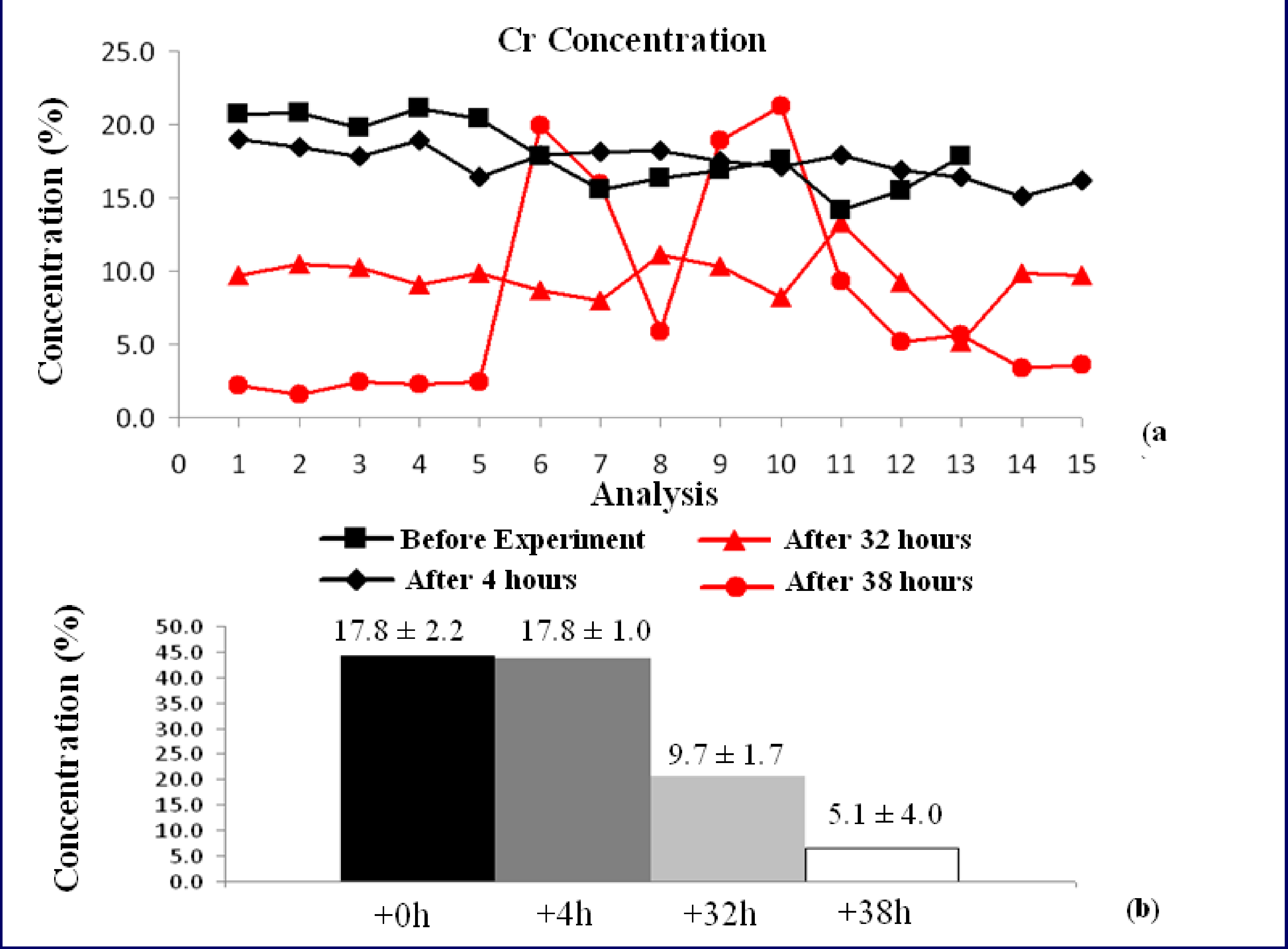
Cr Concentration
Concentration (%)
10.0
8.0
6.0
4.0
2.0
0.0
After 38 hours
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Analysis
(a)
Concentration (%)
4.0
3.0
2.0
1.0
0.0
3.0 ± 1.0
+0h
+4h
+32h
+38h
(b)



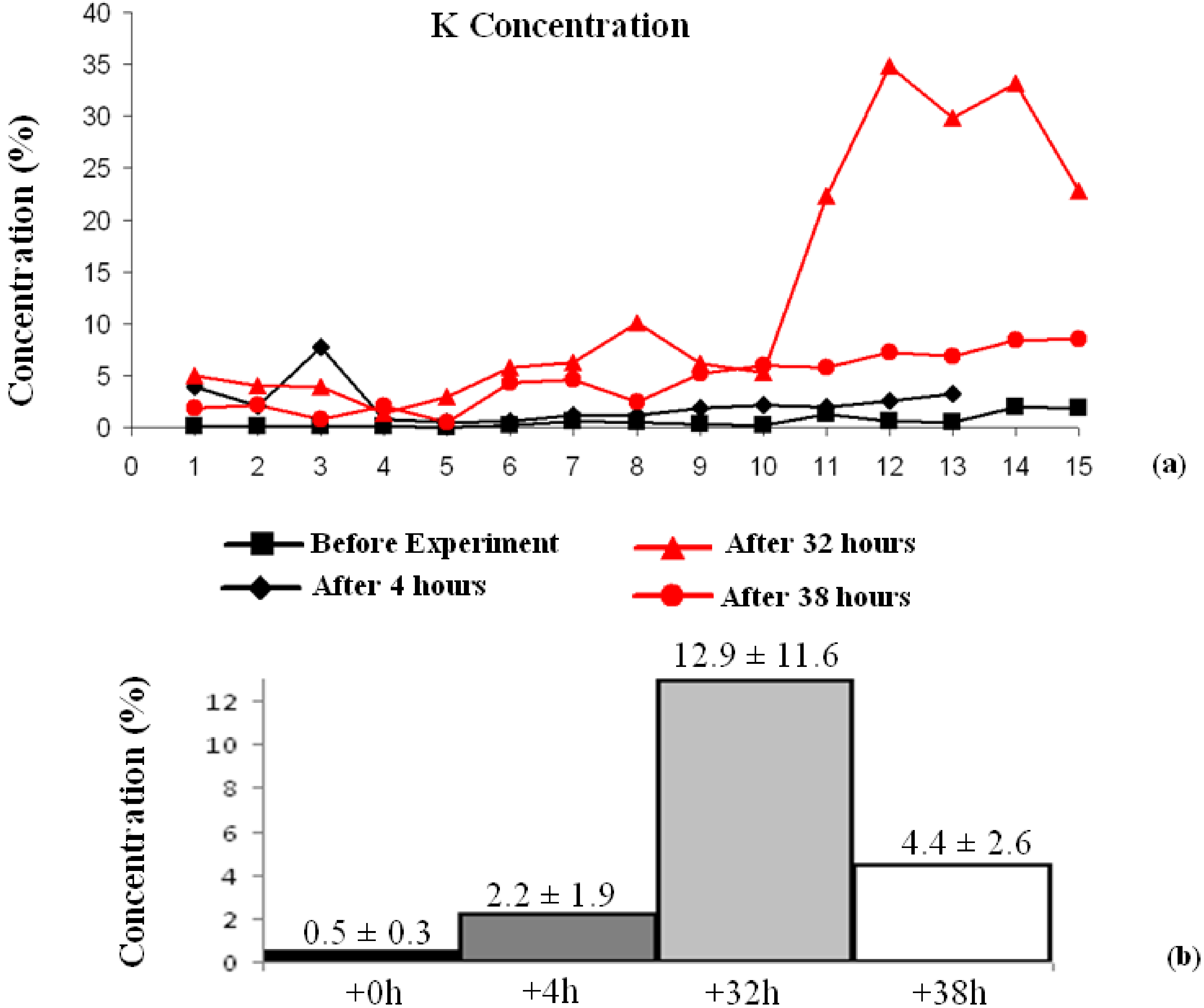
Co Concentration
Concentration (%)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Analysis
(a)
Before Experiment
After 4 hours
After 32 hours
After 38 hours
Concentration (%)
50
40
30
20
10
0
44.1 ± 3.0
43.7 ± 3.1
20.6 ± 2.9
34.4 ± 19.3
+0h
+4h
+32h
+38h
(b)



Fe Concentration
Concentration (%)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Analysis
(a)
Before Experiment
After 32 hours
After 4 hours
After 38 hours
Concentration (%)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
3.1 ± 2.3
1.6 ± 0.6
26.3 ± 9.6
6.6 ± 3.9
+0h
+4h
+32h
+38h
(b)



Cr Concentration
Concentration (%)
25.0
20.0
15.0
10.0
5.0
0.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Analysis
(a
Before Experiment
After 4 hours
After 32 hours
After 38 hours
Concentration (%)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
17.8 ± 2.2
17.8 ± 1.0
9.7 ± 1.7
5.1 ± 4.0
+0h
+4h
+32h
+38h
(b)



K Concentration
Concentration (%)
40
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
(a)
Before Experiment
After 4 hours
After 32 hours
After 38 hours
Concentration (%)
12
10
8
6
4
2
0
0.5 ± 0.3
2.2 ± 1.9
12.9 ± 11.6
4.4 ± 2.6
+0h
+4h
+32h
+38h
(b)