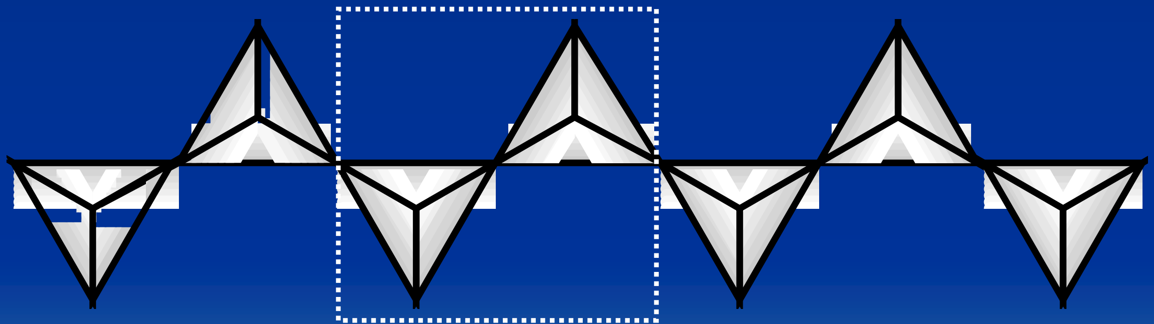
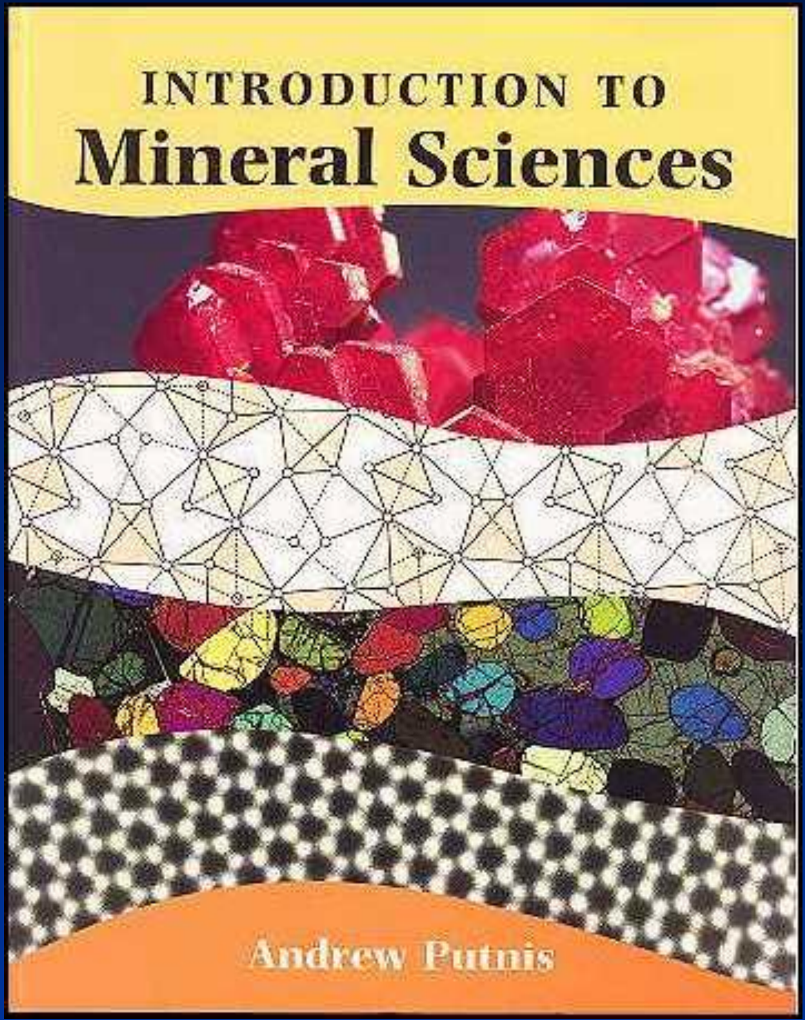
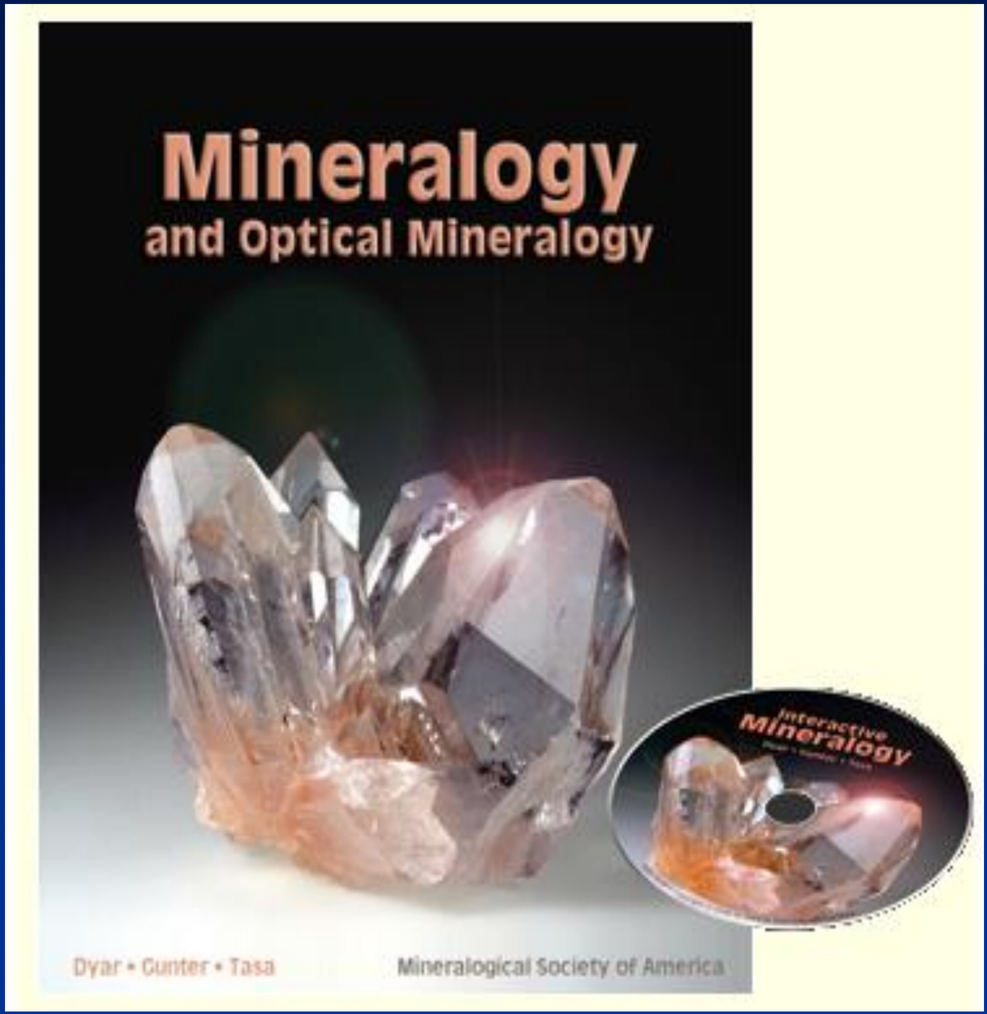
ΟΜΑΔΑ ΠΥΡΟΞΕΝΩΝ

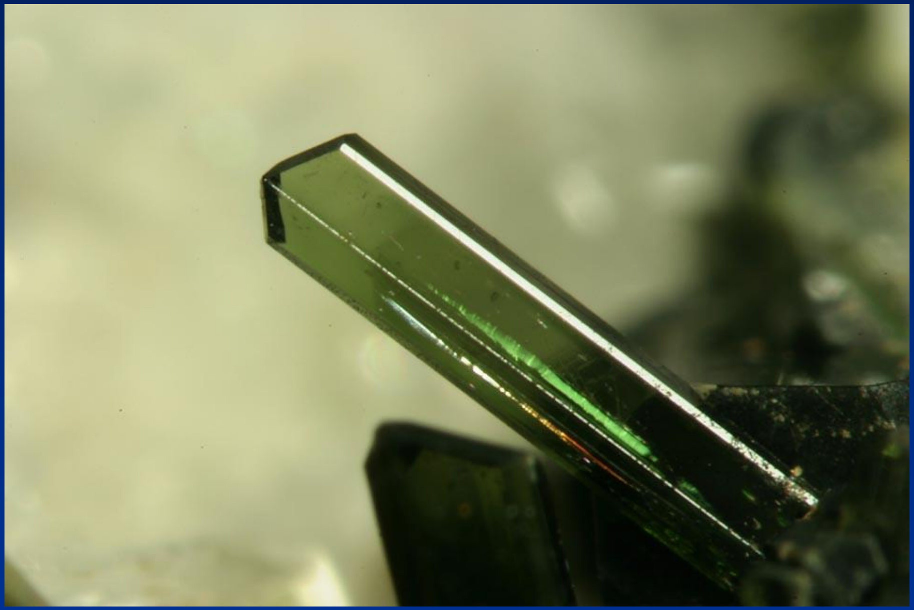
PYROXENE GROUP




INTRODUCTION TO
Mineral Sciences
Andrew Putnis

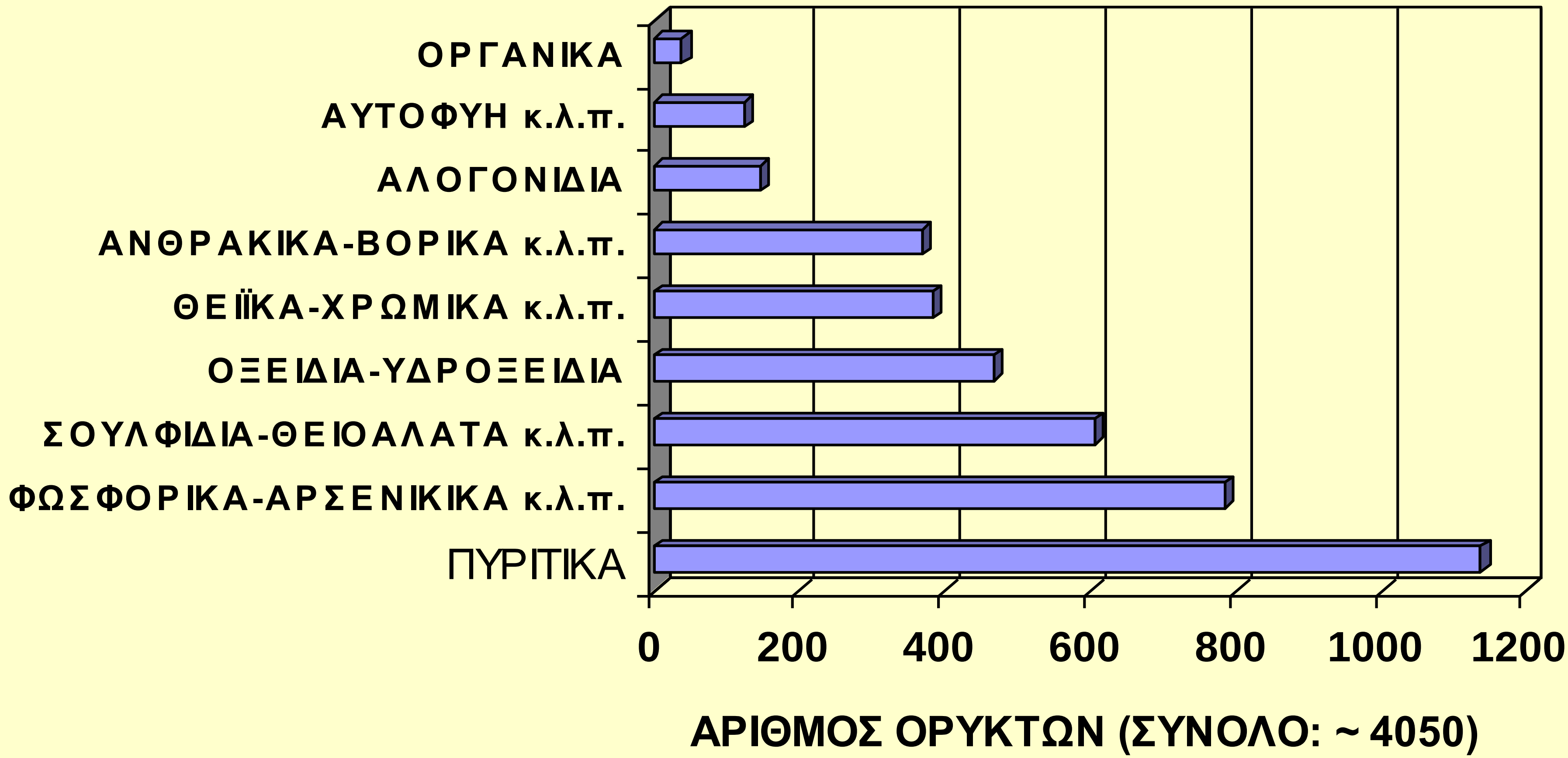

Mineralogy
and Optical Mineralogy
Interactive
Mineralogy
Dyar • Gunter • Tasa
Mineralogical Society of America

ΟΜΑΔΑ ΠΥΡΟΞΕΝΩΝ

http://www.mindat.org

ΟΡΥΚΤΑ



ΟΡΓΑΝΙΚΑ
ΑΥΤΟΦΥΗ κ.λ.π.
ΑΛΟΓΟΝΙΔΙΑ
ΑΝΘΡΑΚΙΚΑ-ΒΟΡΙΚΑ κ.λ.π.
ΘΕΙΪΚΑ-ΧΡΩΜΙΚΑ κ.λ.π.
ΟΞΕΙΔΙΑ-ΥΔΡΟΞΕΙΔΙΑ
ΣΟΥΛΦΙΔΙΑ-ΘΕΙΟΑΛΑΤΑ κ.λ.π.
ΦΩΣΦΟΡΙΚΑ-ΑΡΣΕΝΙΚΙΚΑ κ.λ.π.
ΠΥΡΙΤΙΚΑ
0
200
400
600
800
1000
1200
ΑΡΙΘΜΟΣ ΟΡΥΚΤΩΝ (ΣΥΝΟΛΟ: ~ 4050)

ΠΥΡΙΤΙΚΑ ΟΡΥΚΤΑ

VOLUME XXX NUMBER 3

THE JOURNAL OF GEOLOGY

April-May 1922

THE REACTION PRINCIPLE IN PETROGENESIS

N. L. BOWEN
Geophysical Laboratory, Carnegie Institution of Washington

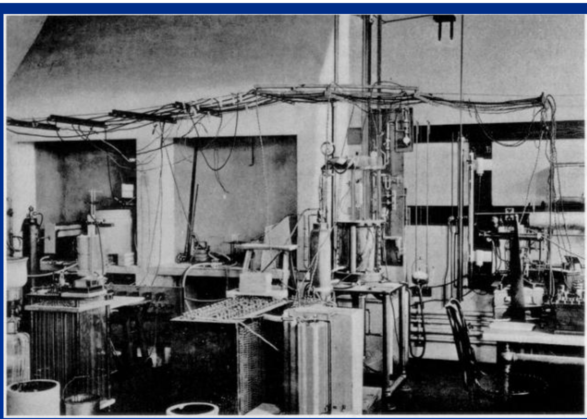
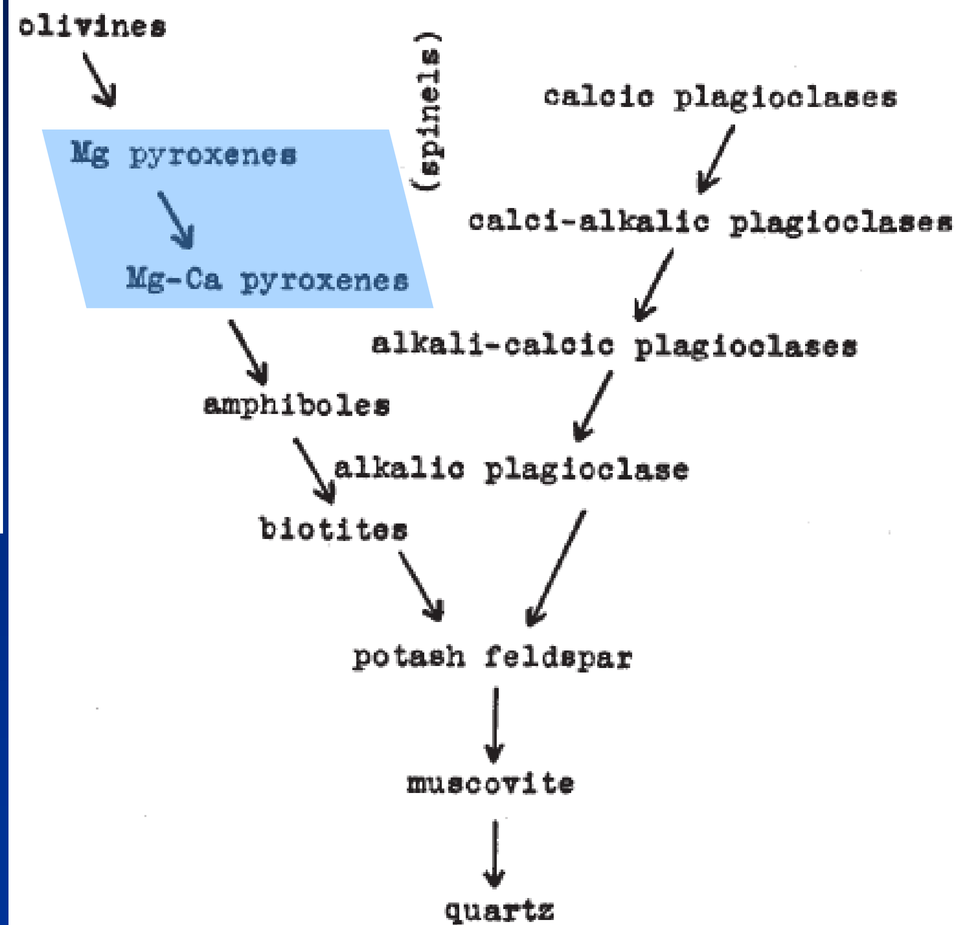


TABLE II

REACTION SERIES IN SUB-ALKALINE ROCKS



ΠΥΡΙΤΙΚΑ ΟΡΥΚΤΑ

Journal of The American Ceramic Society—Osborn 1950 Vol. 33, No. 7

Segregation of Elements During the Crystallization of a Magma

by **E. F. OSBORN**

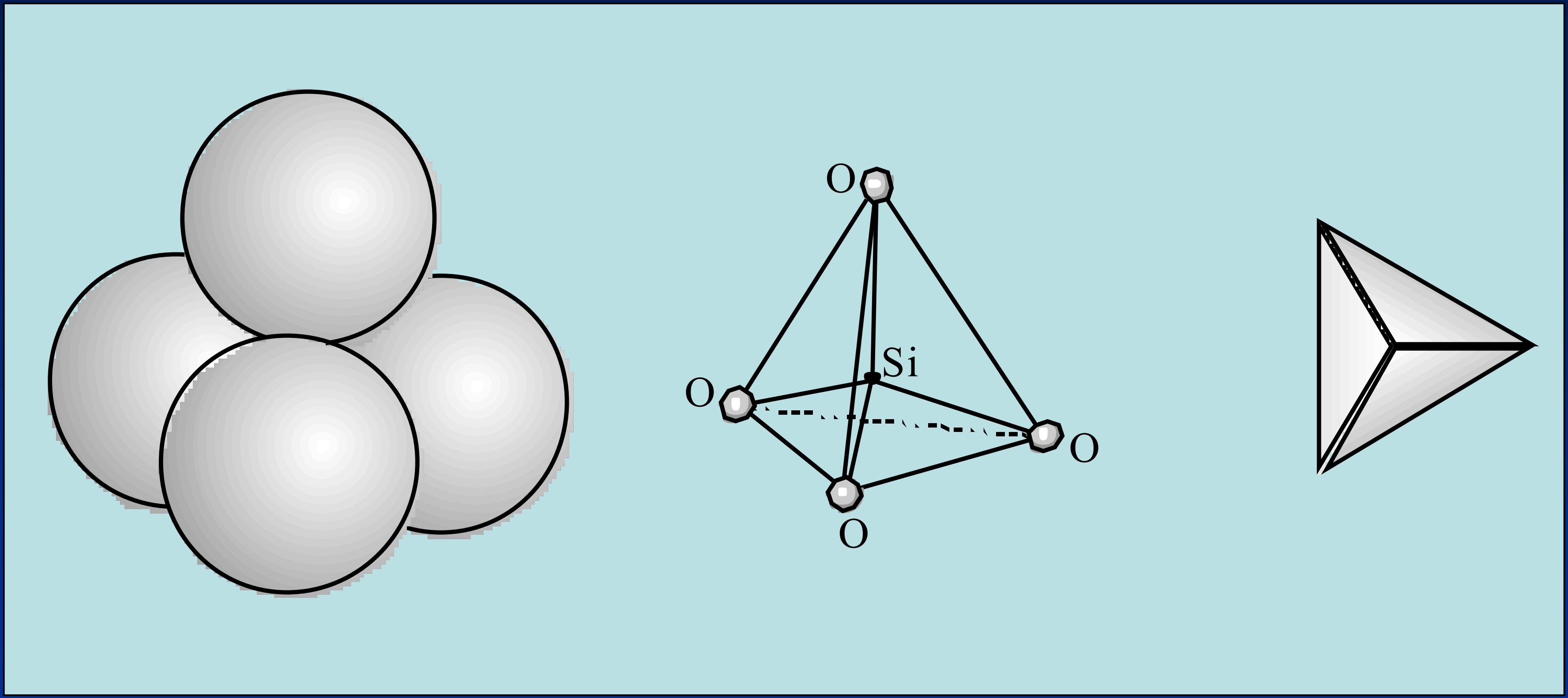
Department of Earth Sciences, School of Mineral Industries, The Pennsylvania State College, State College, Pennsylvania

to react with the liquid to form minerals occurring lower down in the series. Olivine reacts with the liquid to form pyroxene (MgO–FeO–CaO metasilicate) as in the familar relation of forsterite (Mg_2SiO_4) to clinoenstatite ($MgSiO_3$), and plagioclase continually reacts with the liquid to form a more sodic member of the series. If equilibrium were maintained throughout the

causing a relative enrichment of the liquid in Na^+ and Fe^{2+}. Both Al^{3+} and Fe^{3+}, which could not enter the olivine structure, are fixed in small to moderate amounts in the pyroxenes.

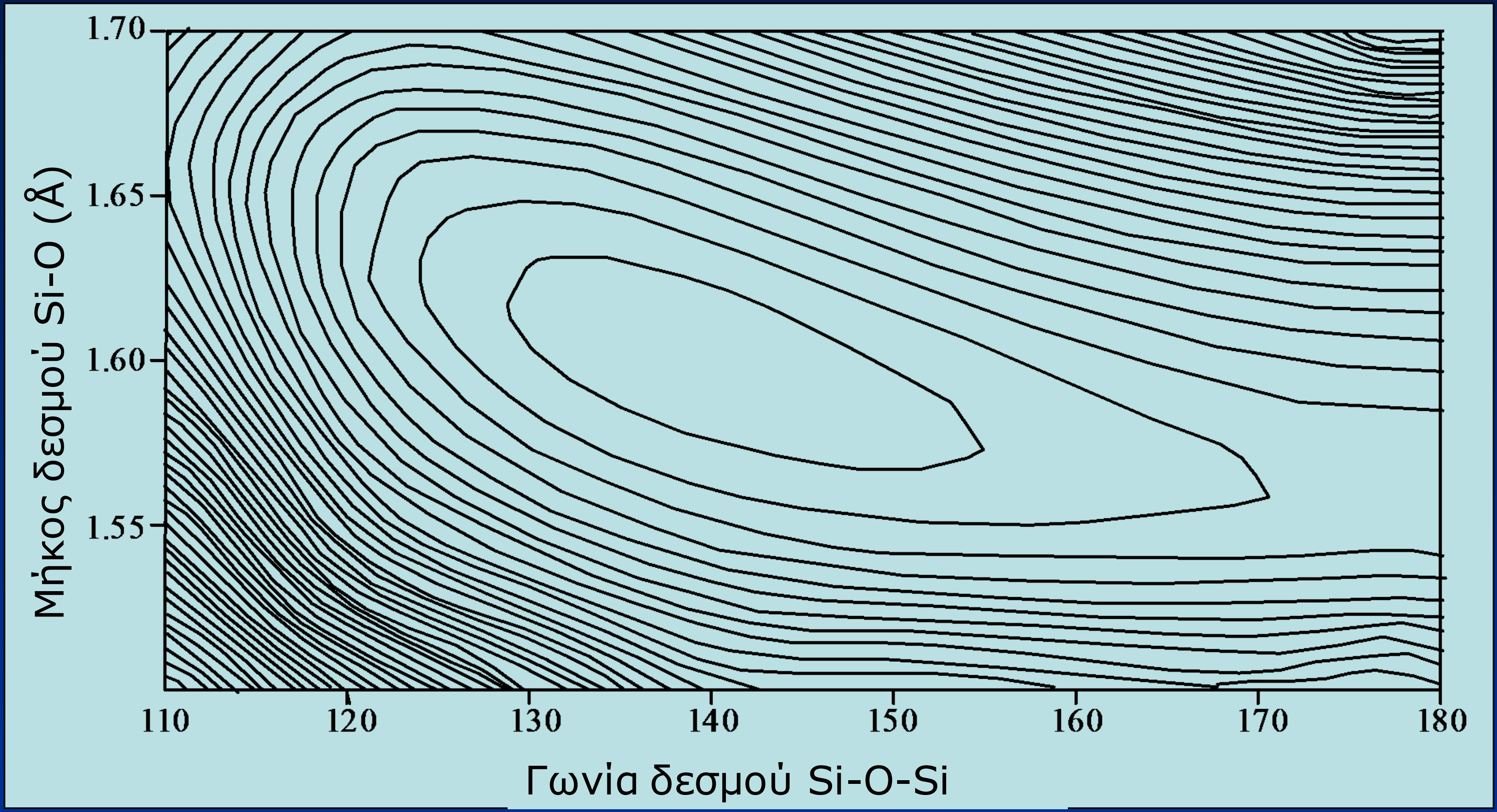
This outline of ionic and structural relationships existing

ΠΥΡΙΤΙΚΑ ΟΡΥΚΤΑ



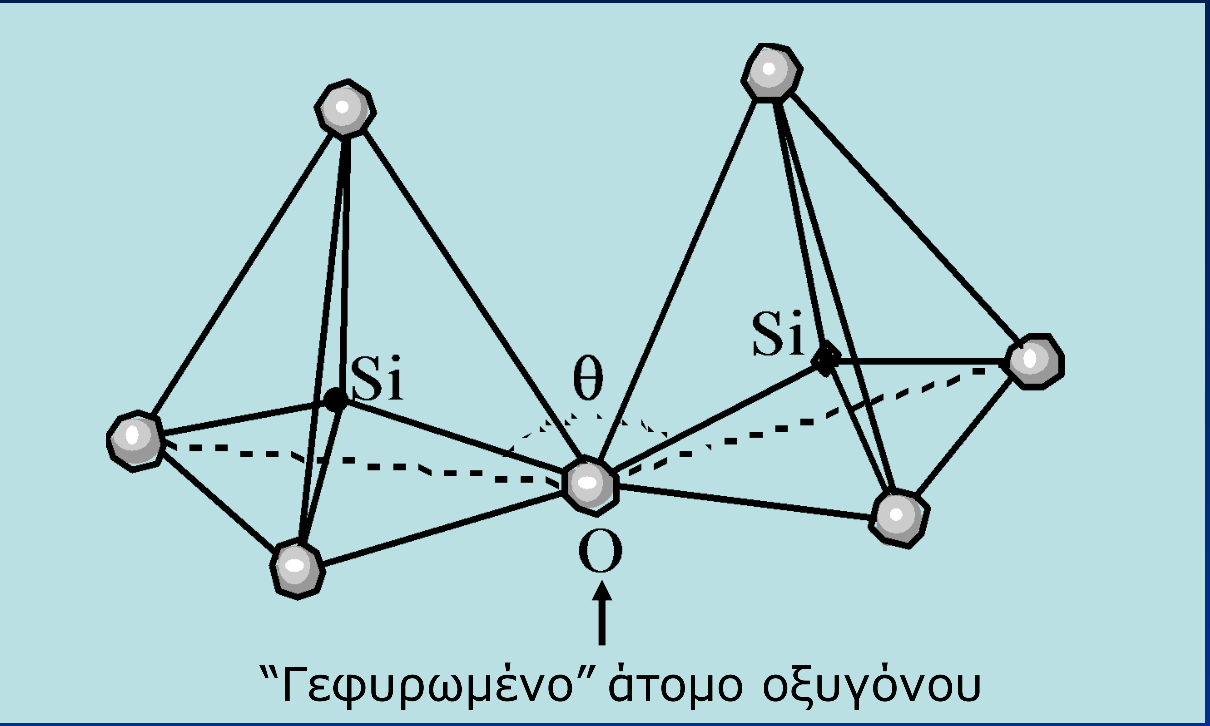
Το πυριτικό τετράεδρο: $[SiO_4]^{4-}$
(Si:O=1:4)

ΠΥΡΙΤΙΚΑ ΟΡΥΚΤΑ



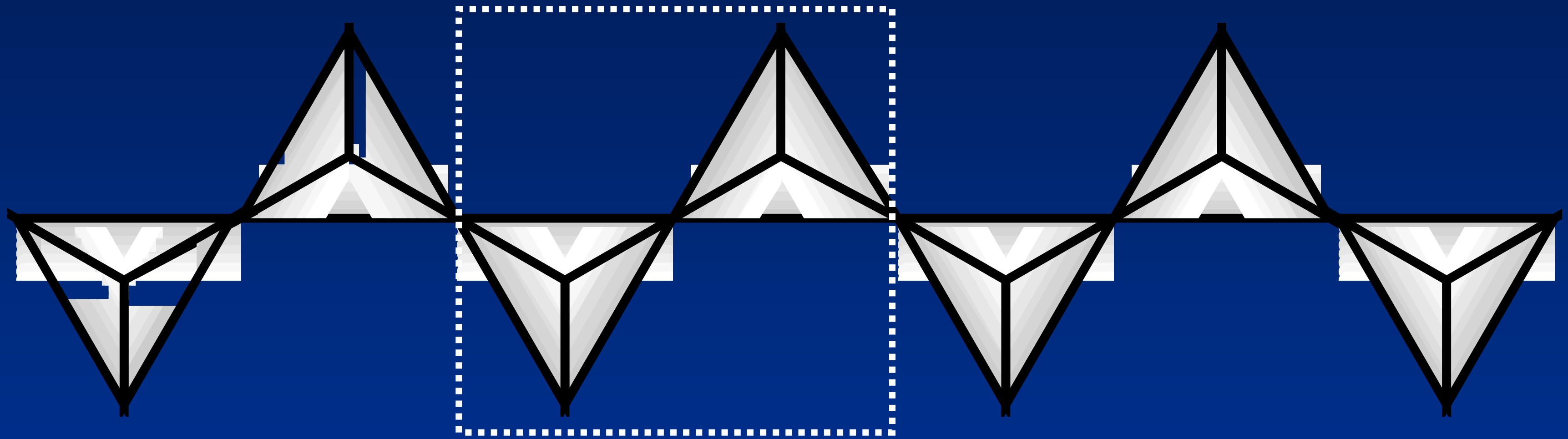
Το πυριτικό τετράεδρο: $[SiO_4]^{4-}$

ΠΥΡΙΤΙΚΑ ΟΡΥΚΤΑ



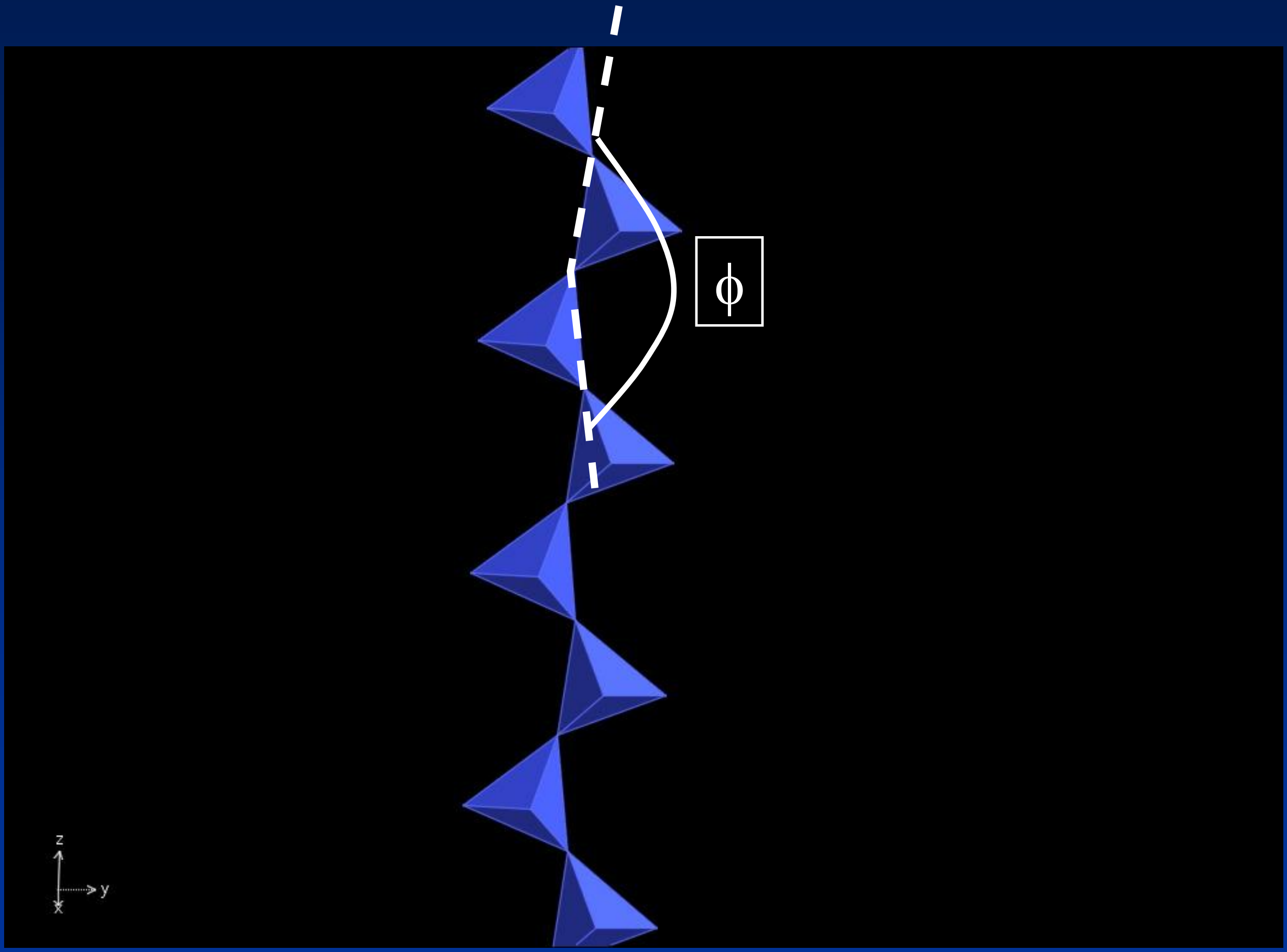
$[Si_2O_7]^{6-}$ (Si:O=2:7)

ΙΝΟΠΥΡΙΤΙΚΑ ΟΡΥΚΤΑ

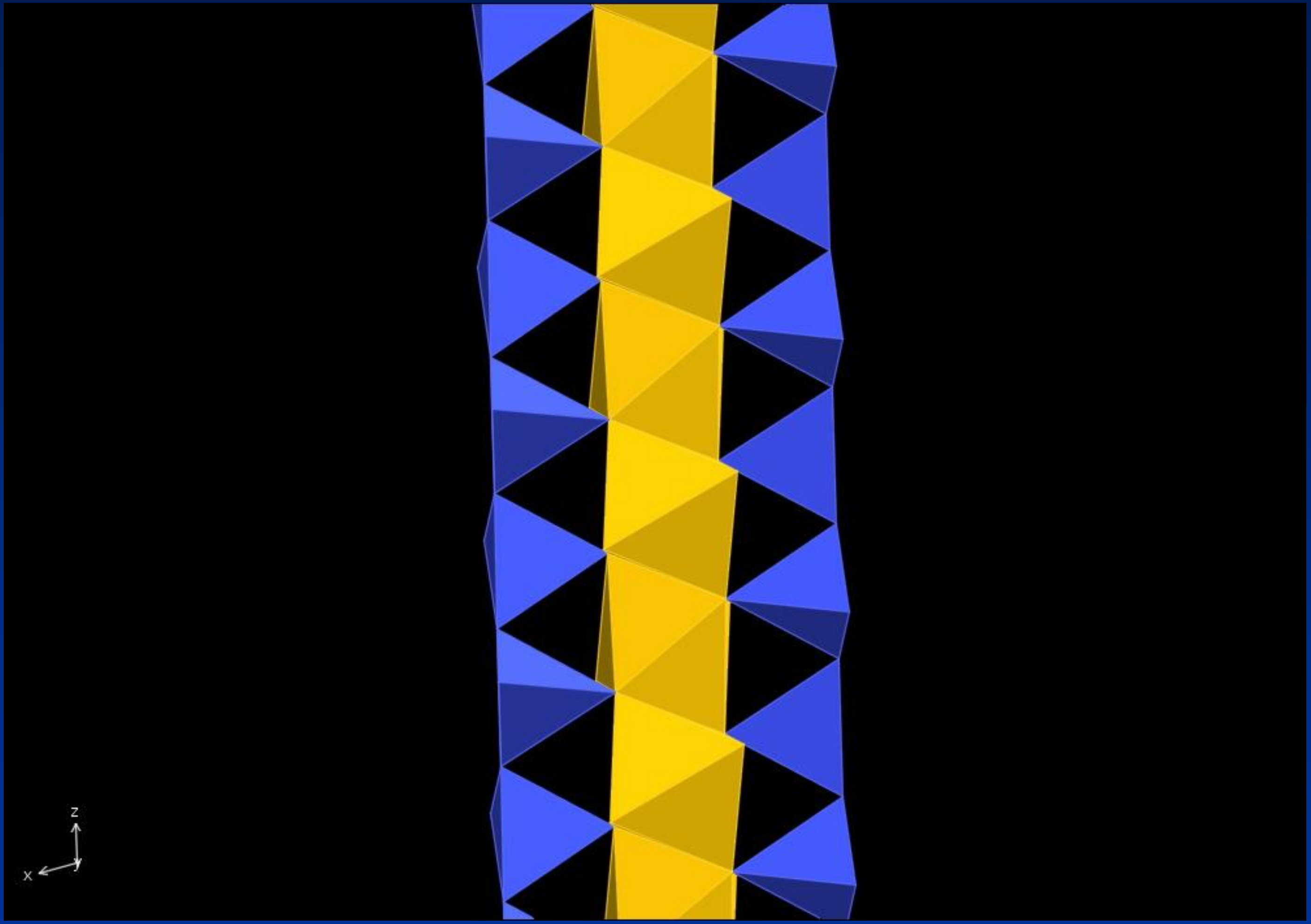


$[Si_2O_6]^{4-}$ (Si:O=1:3)

ΠΥΡΟΞΕΝΟΙ



ΠΥΡΟΞΕΝΟΙ



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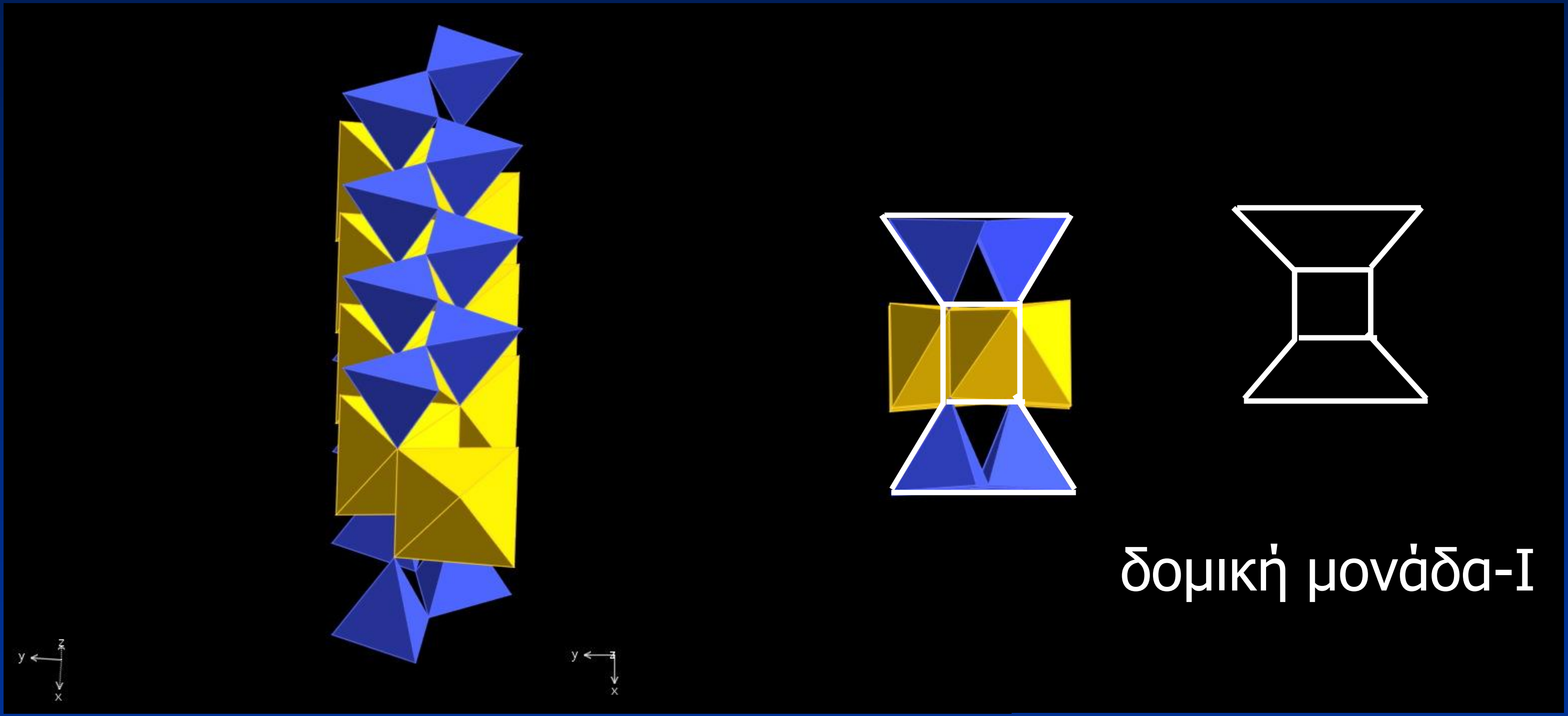
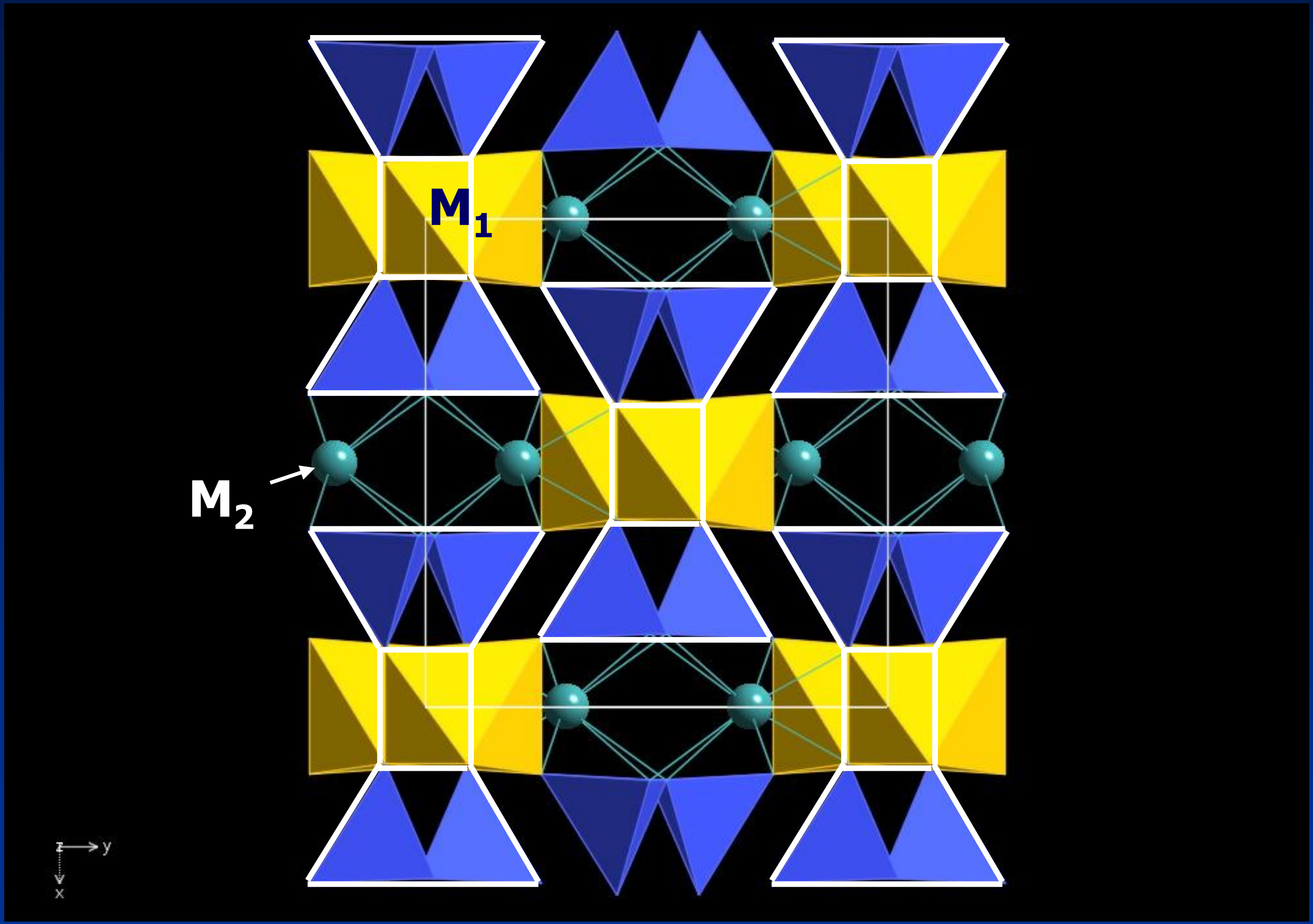
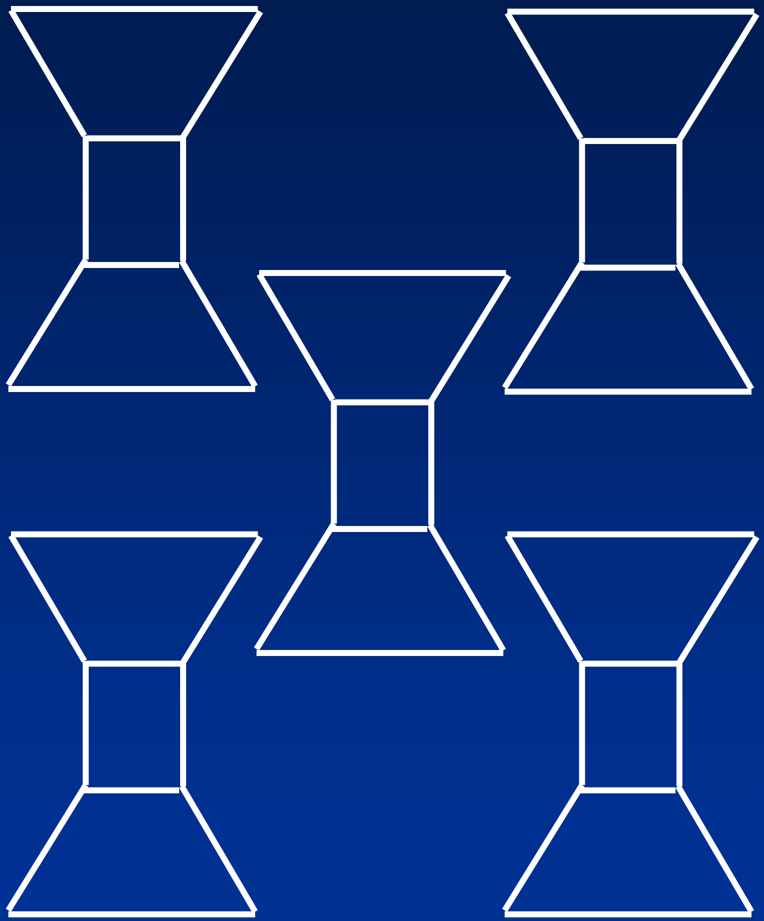


ΠΥΡΟΞΕΝΟΙ



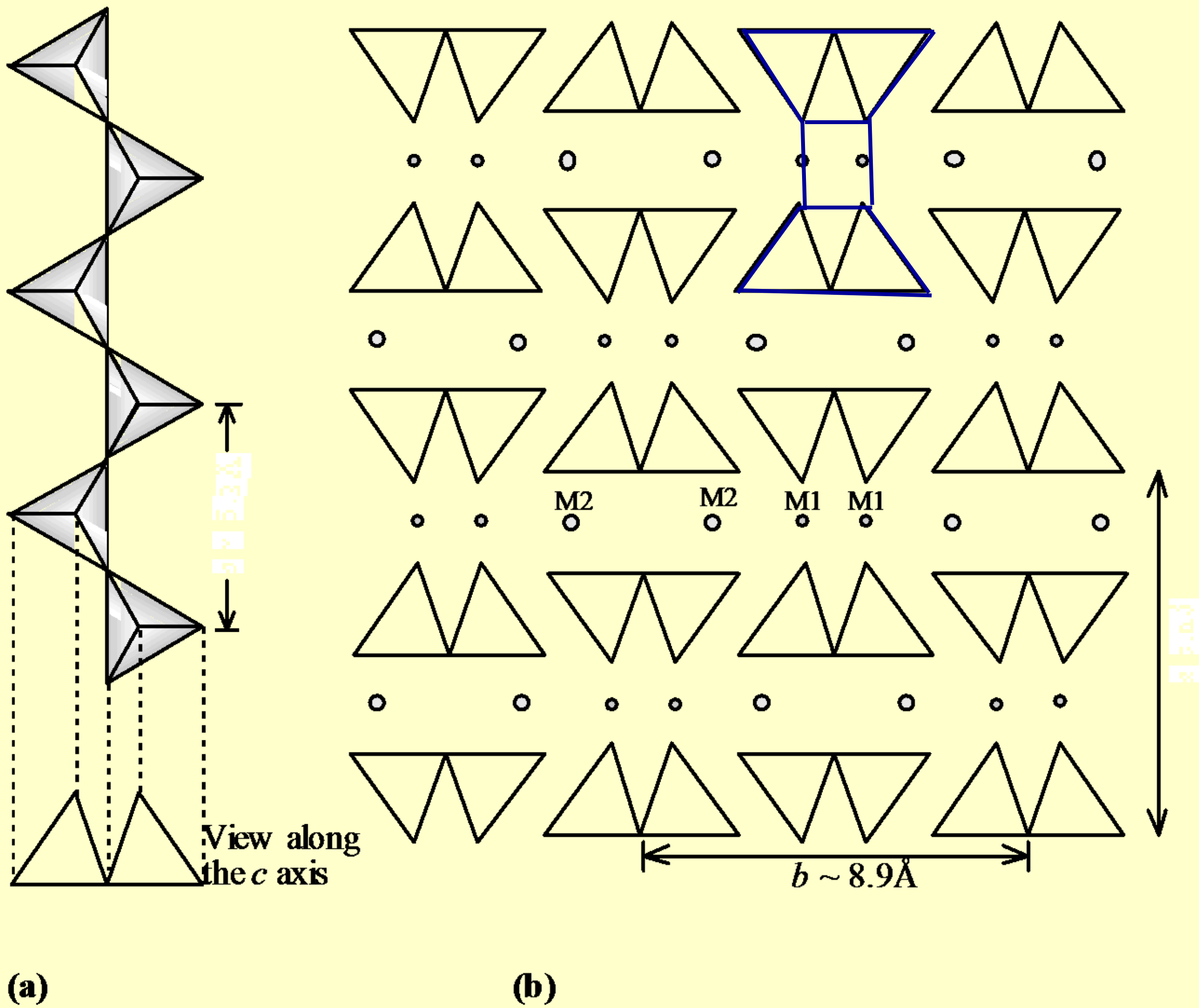
Οι οκταεδρικές θέσεις Μ1 περιέχουν τα μικρότερα κατιόντα (π.χ. Al^{3+}, Fe^{3+}) και οι Μ2 τα μεγαλύτερα κατιόντα (π.χ. Mg^{2+}, Ca^{2+}, Fe^{2+}, Na^{+})

ΠΥΡΟΞΕΝΟΙ

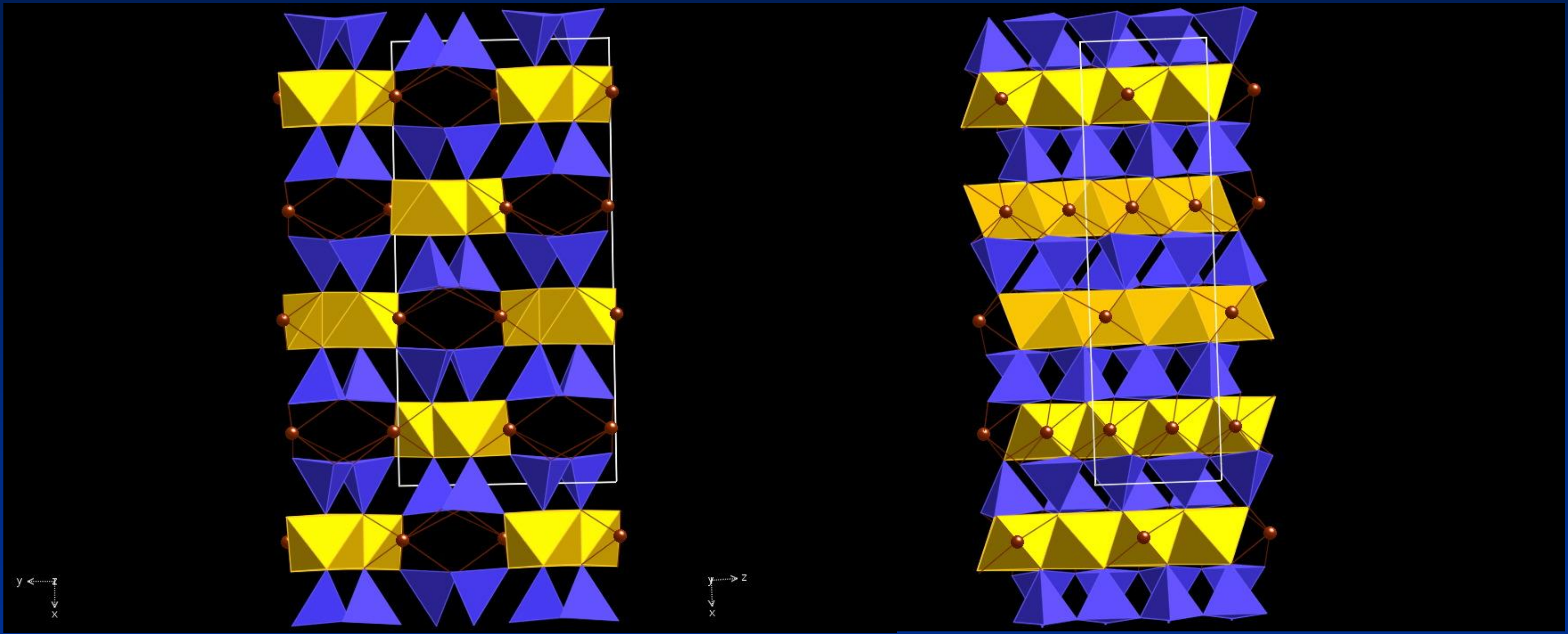


Διευθέτηση δομικών μονάδων - Ι

ΠΥΡΟΞΕΝΟΙ

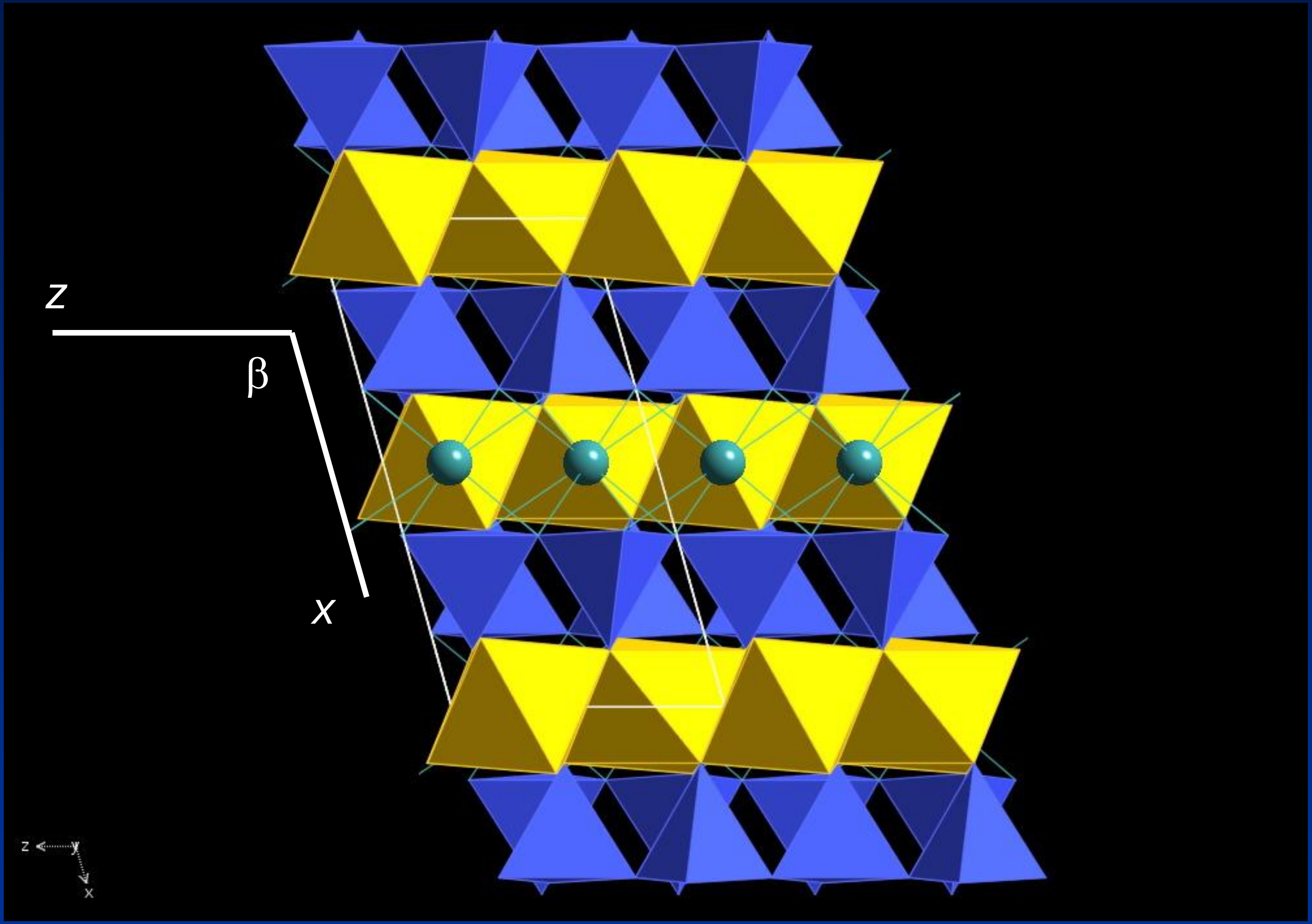


ΟΡΘΟΠΥΡΟΞΕΝΟΙ



Ρομβικοί πυρόξενοι (γενικά M=Mg,Fe)

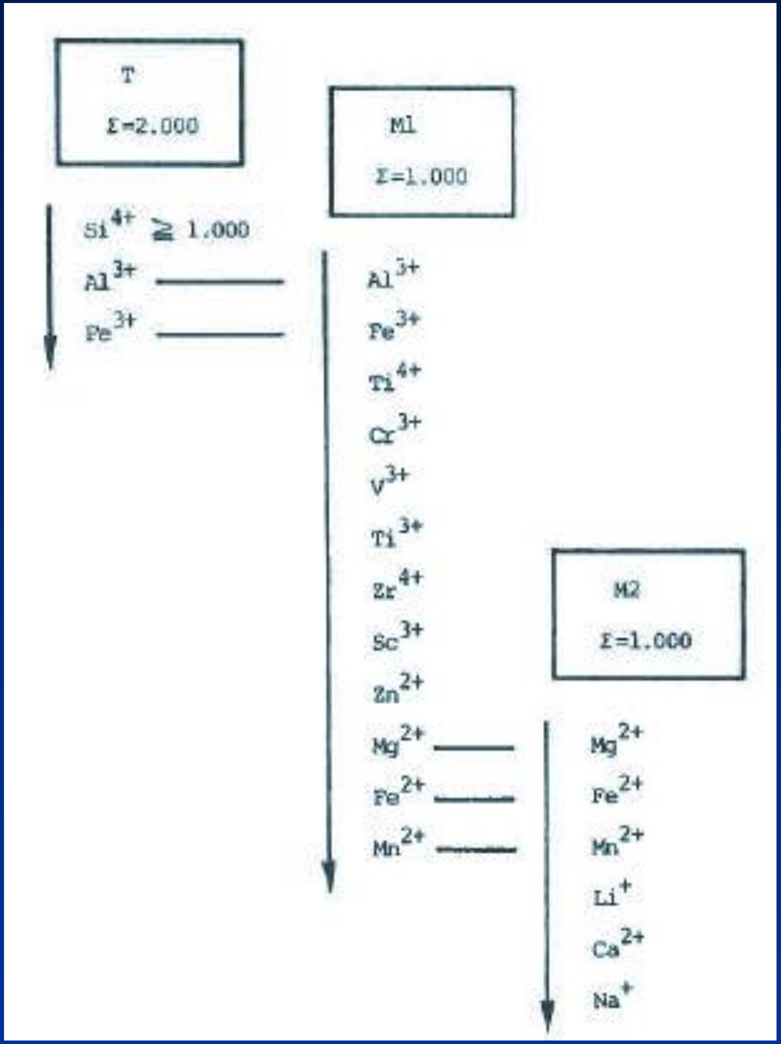
ΚΛΙΝΟΠΥΡΟΞΕΝΟΙ



Μονοκλινείς πυρόξενοι (γενικά M=Mg,Fe,Ca,Na)

ΠΥΡΟΞΕΝΟΙ

$M_2M_1T_2O_6$



American Mineralogist, Volume 73, pages 1123–1133, 1988

Nomenclature of pyroxenes

Subcommittee on Pyroxenes

Commission on New Minerals and Mineral Names
International Mineralogical Association

N. MORIMOTO, Chairman
Department of Geology and Mineralogy, Kyoto University, Kyoto 606, Japan

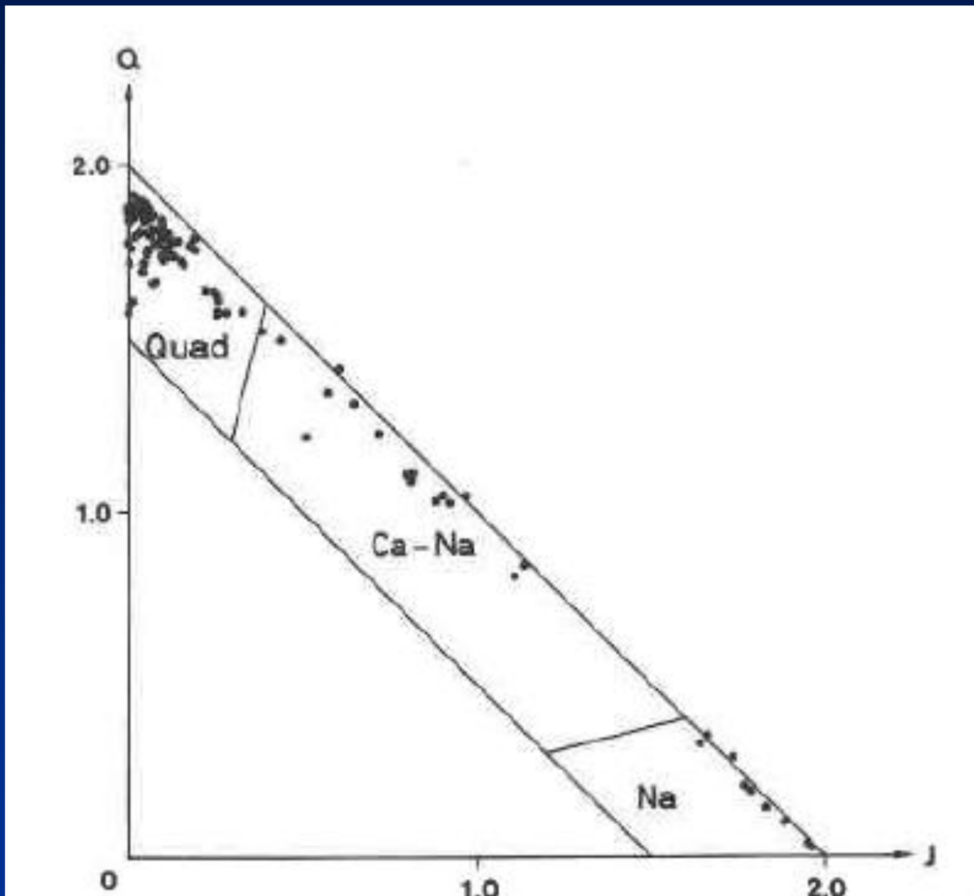
Subcommittee Members
J. FABRIES (France), A. K. FERGUSON (Australia) I. V. GINZBURG (USSR), M. ROSS (U.S.A.), F. A. SEIFERT (Germany), J. ZUSSMAN (U.K.)

Nonvoting Members
K. AOKI (Japan), G. GOTTARDI (Italy)

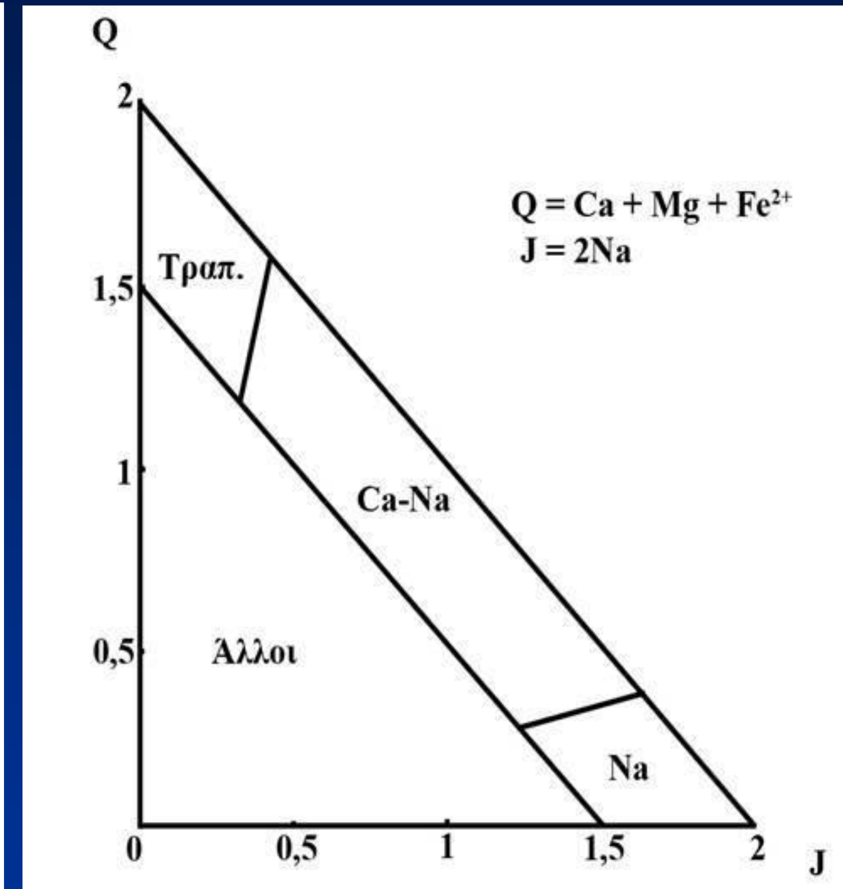
ABSTRACT

This is the final report on the nomenclature of pyroxenes by the Subcommittee on Pyroxenes established by the Commission on New Minerals and Mineral Names of the International Mineralogical Association. The recommendations of the Subcommittee as put forward in this report have been formally accepted by the Commission. Accepted and widely used names have been chemically defined, by combining new and conventional methods, to agree as far as possible with the consensus of present use. Twenty names are formally accepted, among which thirteen are used to represent the end members of definite chemical compositions. In common binary solid-solution series, species names are given to the two end members by the "50% rule." Adjectival modifiers for pyroxene mineral names are defined to indicate unusual amounts of chemical constituents. This report includes a list of 105 previously used pyroxene names that have been formally discarded by the Commission.

ΠΥΡΟΞΕΝΟΙ

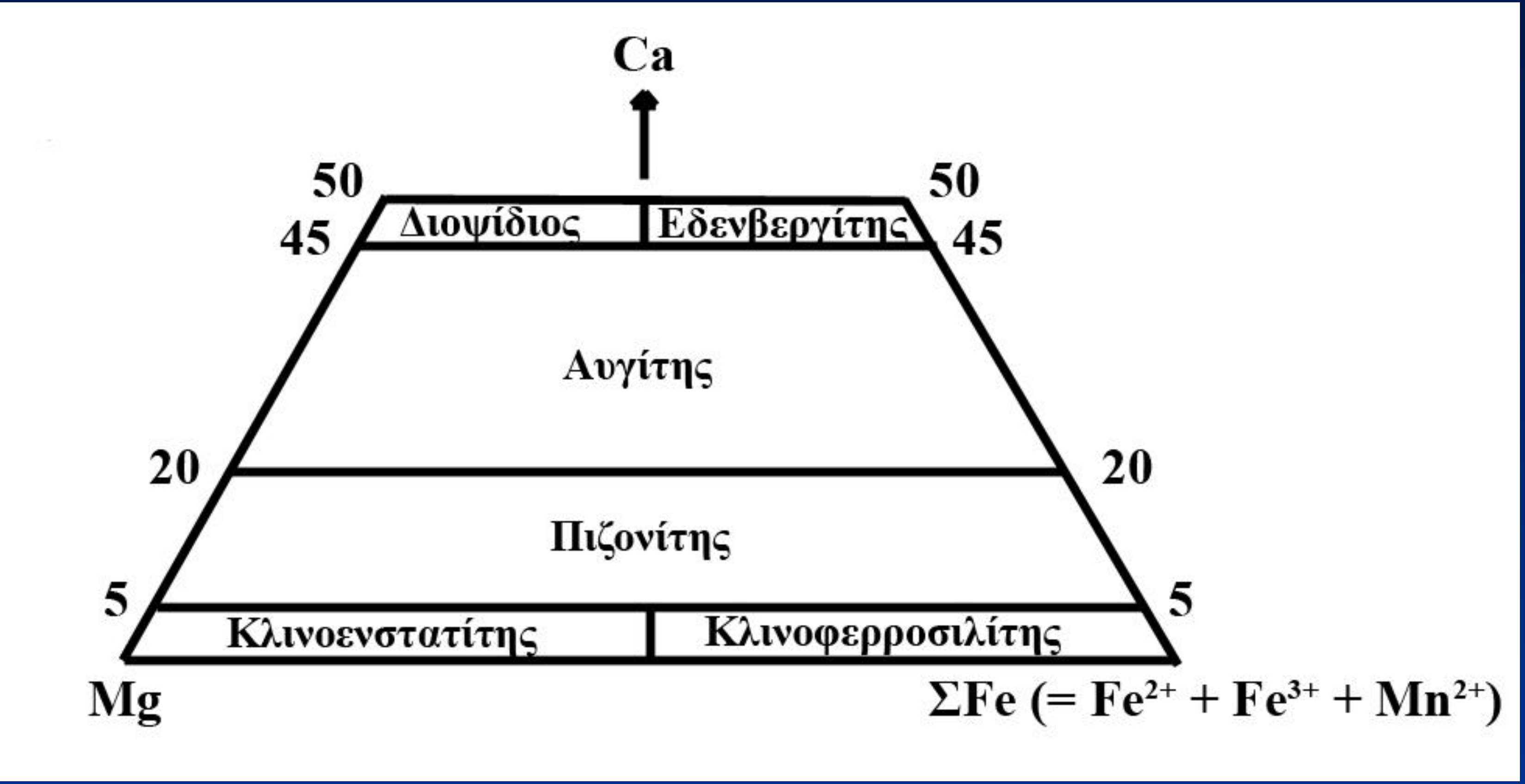


Q
2.0
1.0
0
Quad
Ca – Na
Na
1.0
2.0
J



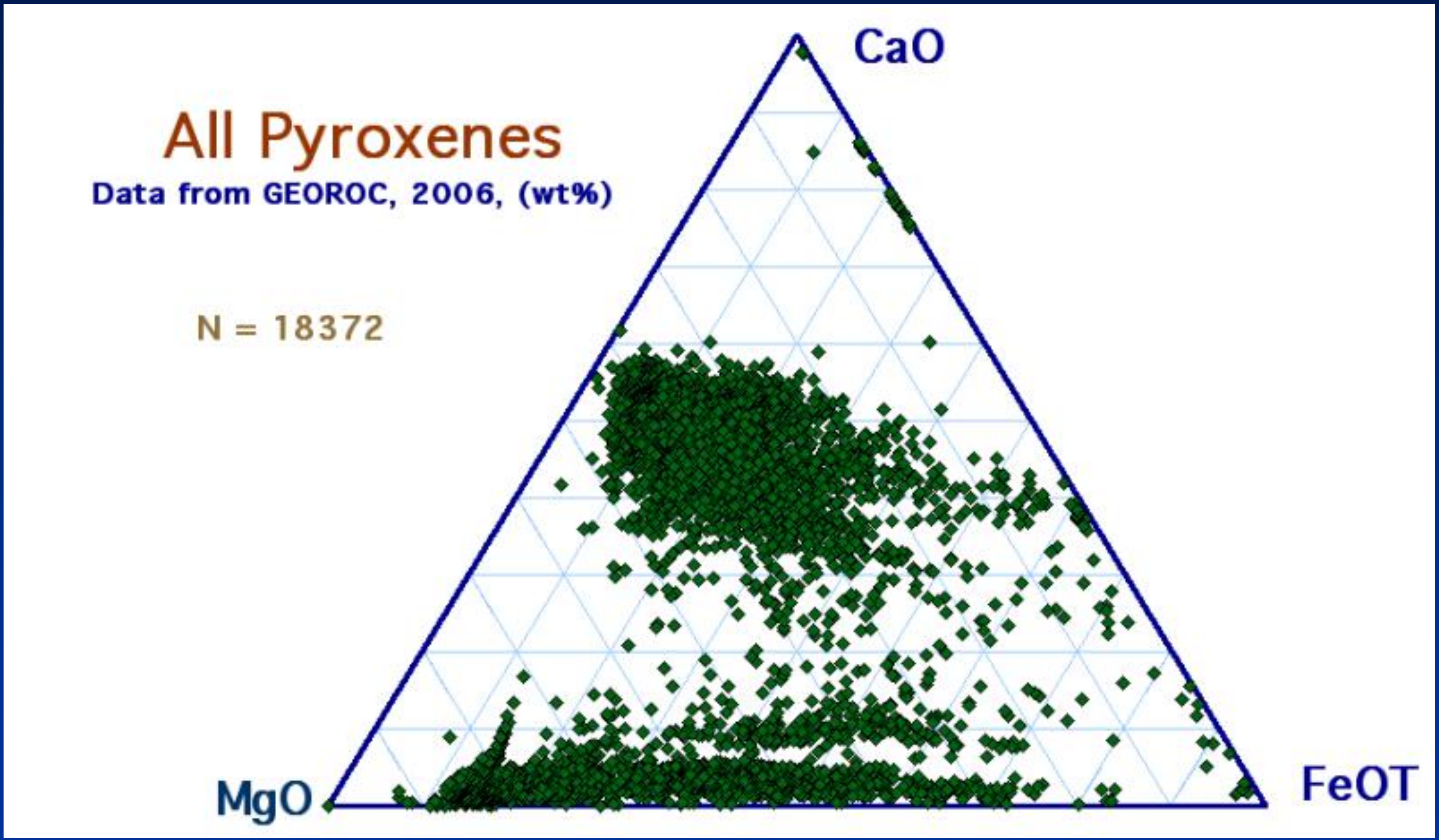
Q
2
1,5
1
0,5
0
Q = Ca + Mg + Fe2+
J = 2Na
Τραπ.
Ca-Na
Άλλοι
Na
0,5
1
1,5
2
J

Mg,Fe,Ca-ΠΥΡΟΞΕΝΟΙ

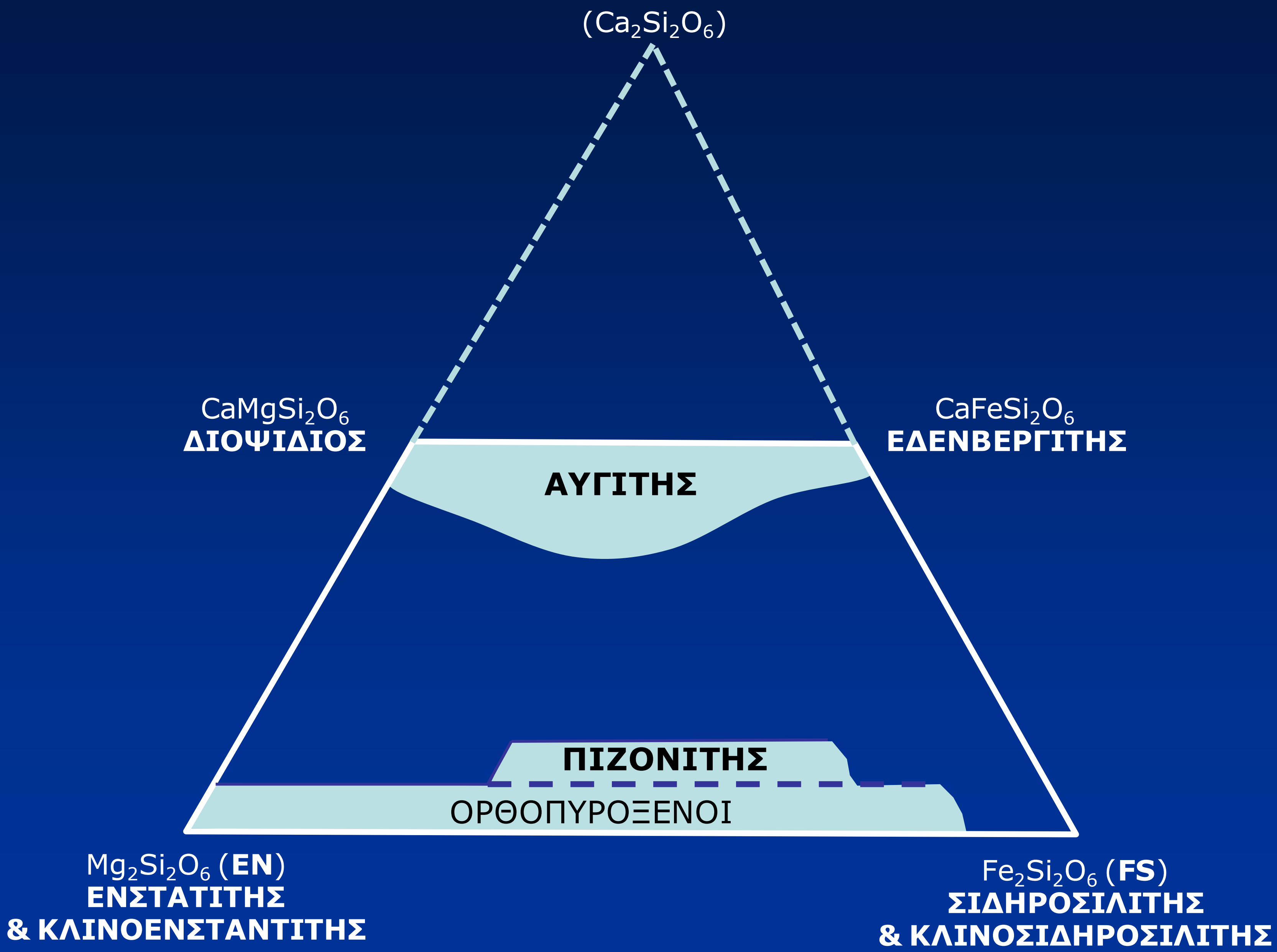


- $Ca = 100Ca/(Ca+Mg+\Sigma Fe)$
- $Mg = 100Mg/(Ca+Mg+\Sigma Fe)$
- $\Sigma Fe = 100Fe/(Ca+Mg+\Sigma Fe)$

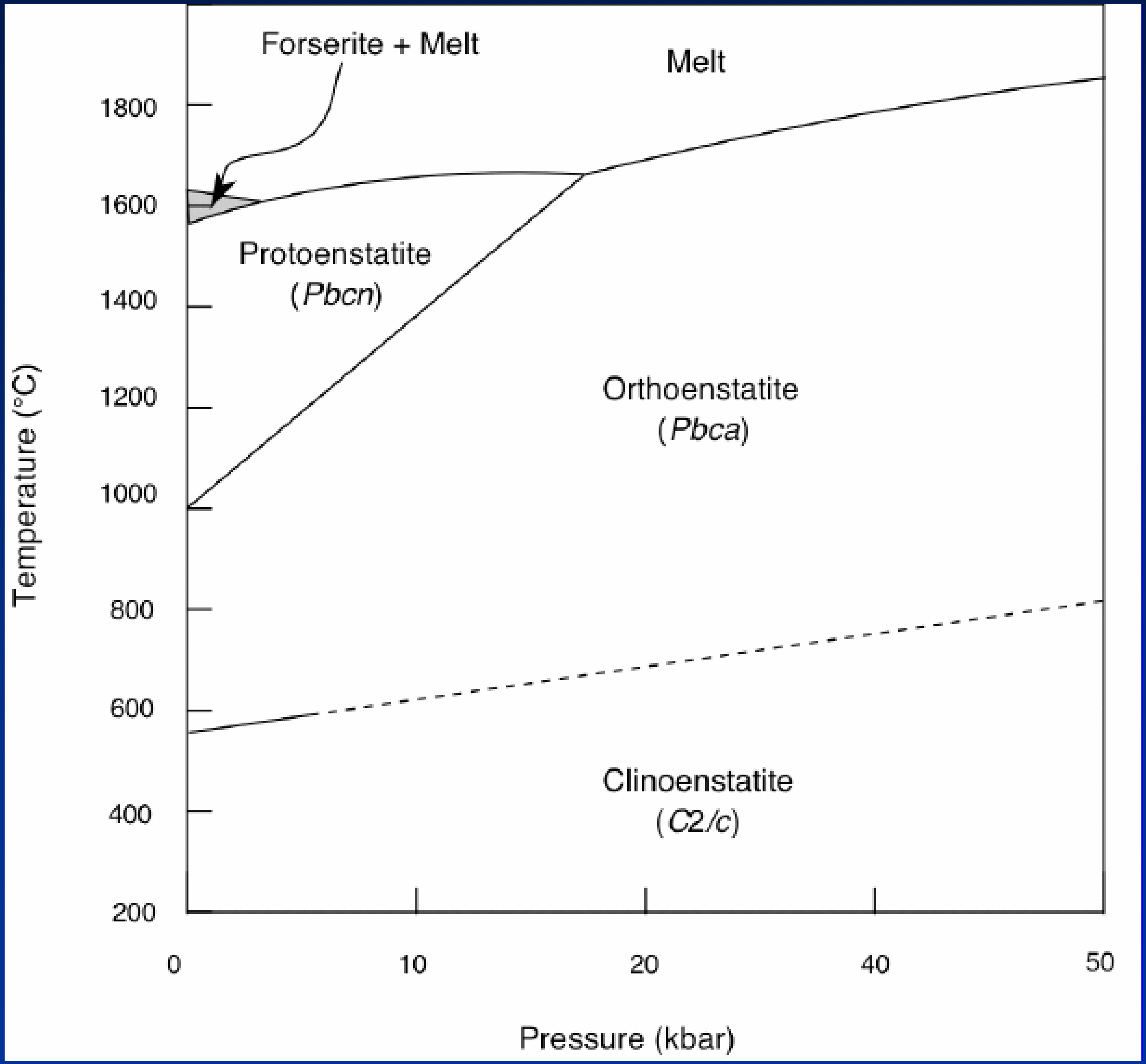
http://www.geokem.com/



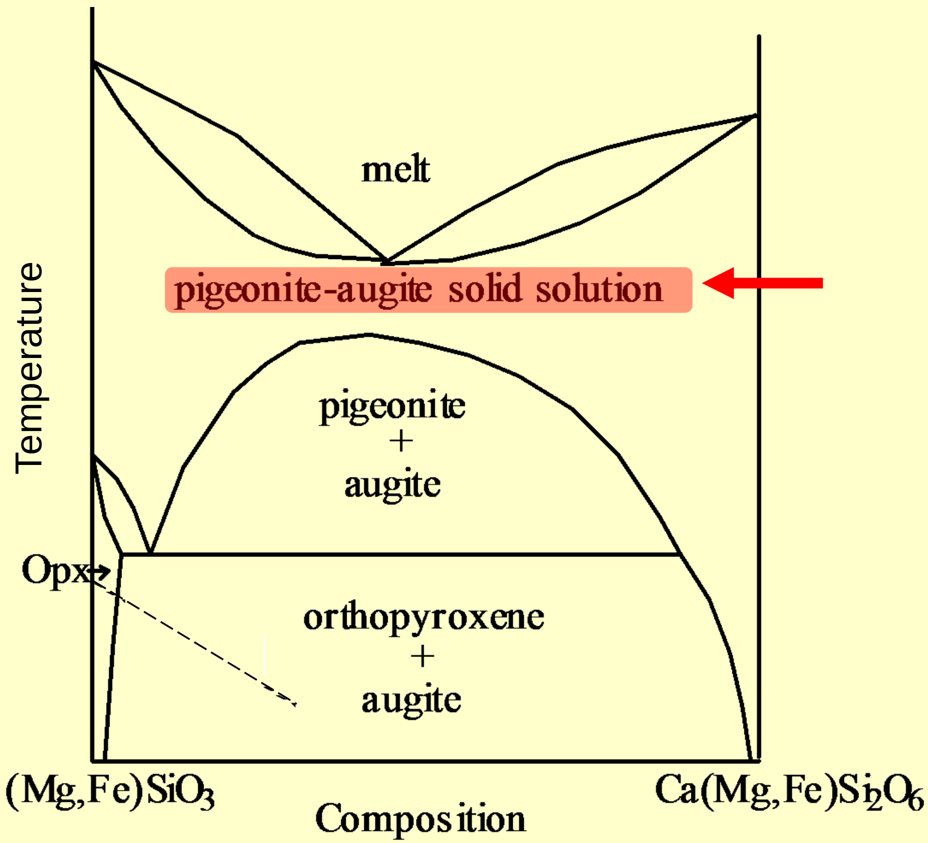
Mg,Fe,Ca-ΠΥΡΟΞΕΝΟΙ

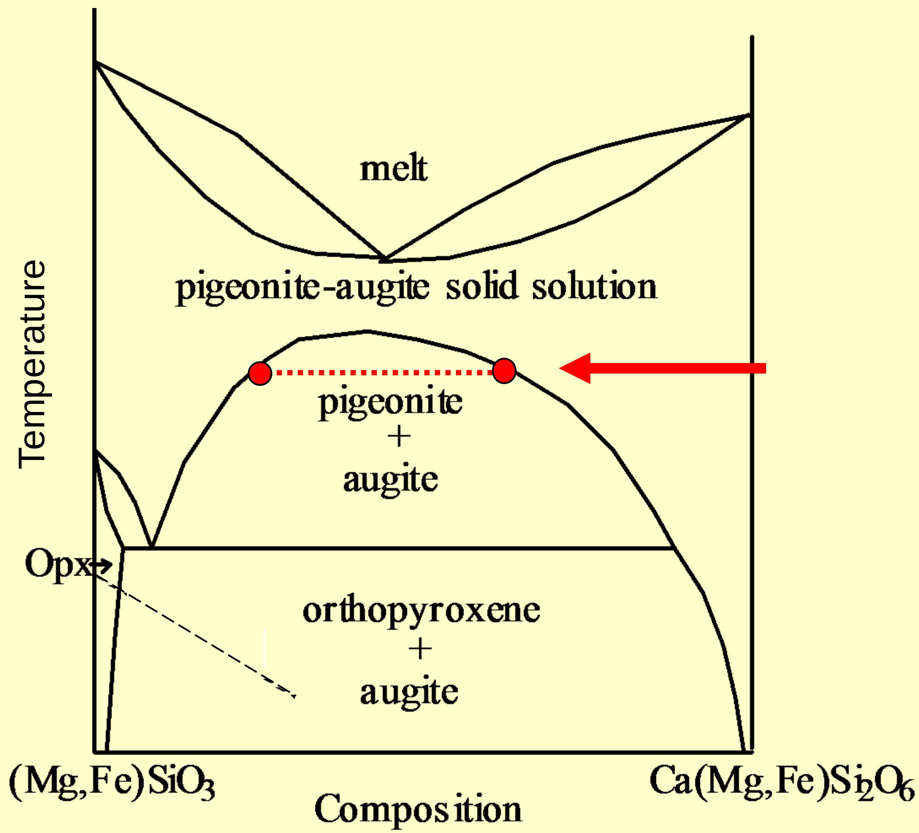


Mg,Fe,Ca-ΠΥΡΟΞΕΝΟΙ



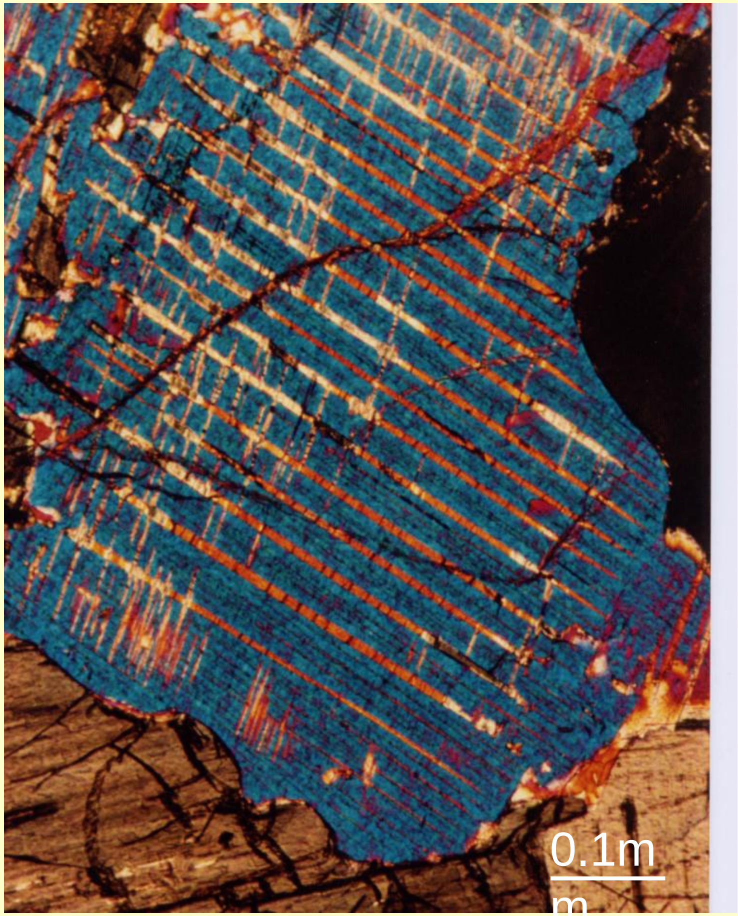
Mg,Fe,Ca-ΠΥΡΟΞΕΝΟΙ



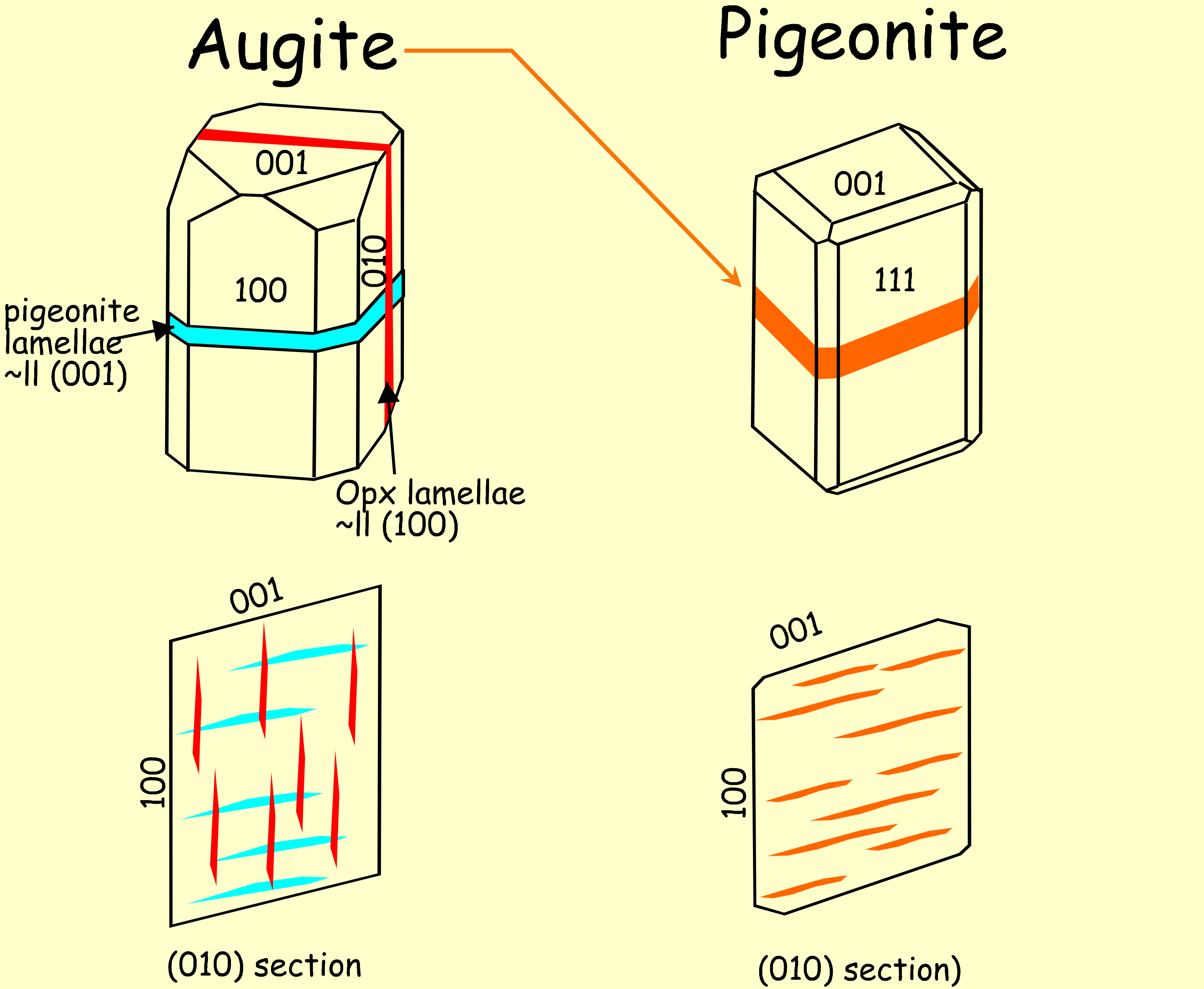


ΑΠΟΜΕΙΞΗ (EXSOLUTION)

Mg,Fe,Ca-ΠΥΡΟΞΕΝΟΙ

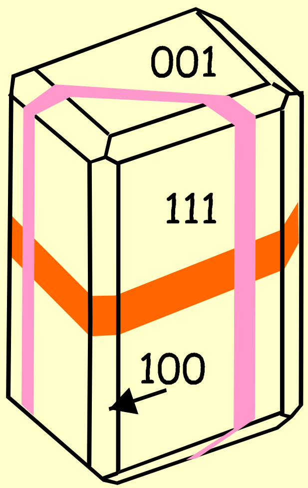


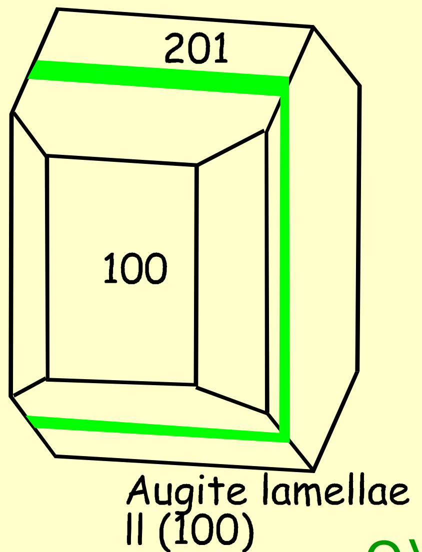
Η κλίμακα της μικροδομής της απόμειξης εξαρτάται από την ταχύτητα ψύξης


Augite
Pigeonite
001
100
010
pigeonite lamellae ~ll (001)
Opx lamellae ~ll (100)
001
111
001
100
(010) section
001
100
(010) section)

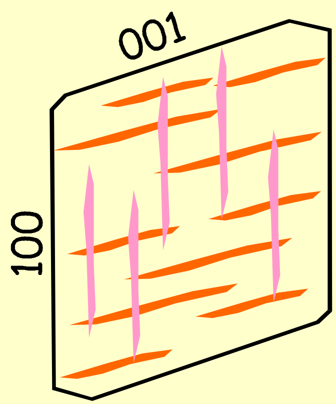
OPX after Pigeonite

Prmary Opx

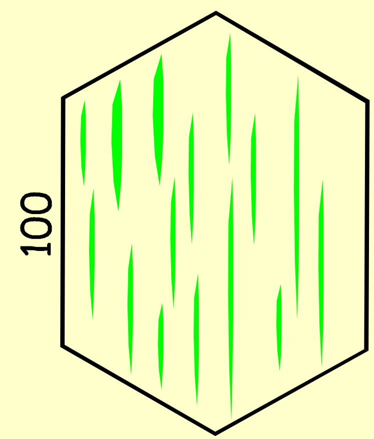




Ολιβίνης+Τήγμα
(ΠΕΡΙΤΗΚΤΙΚΗ
ΑΝΤΙΔΡΑΣΗ)

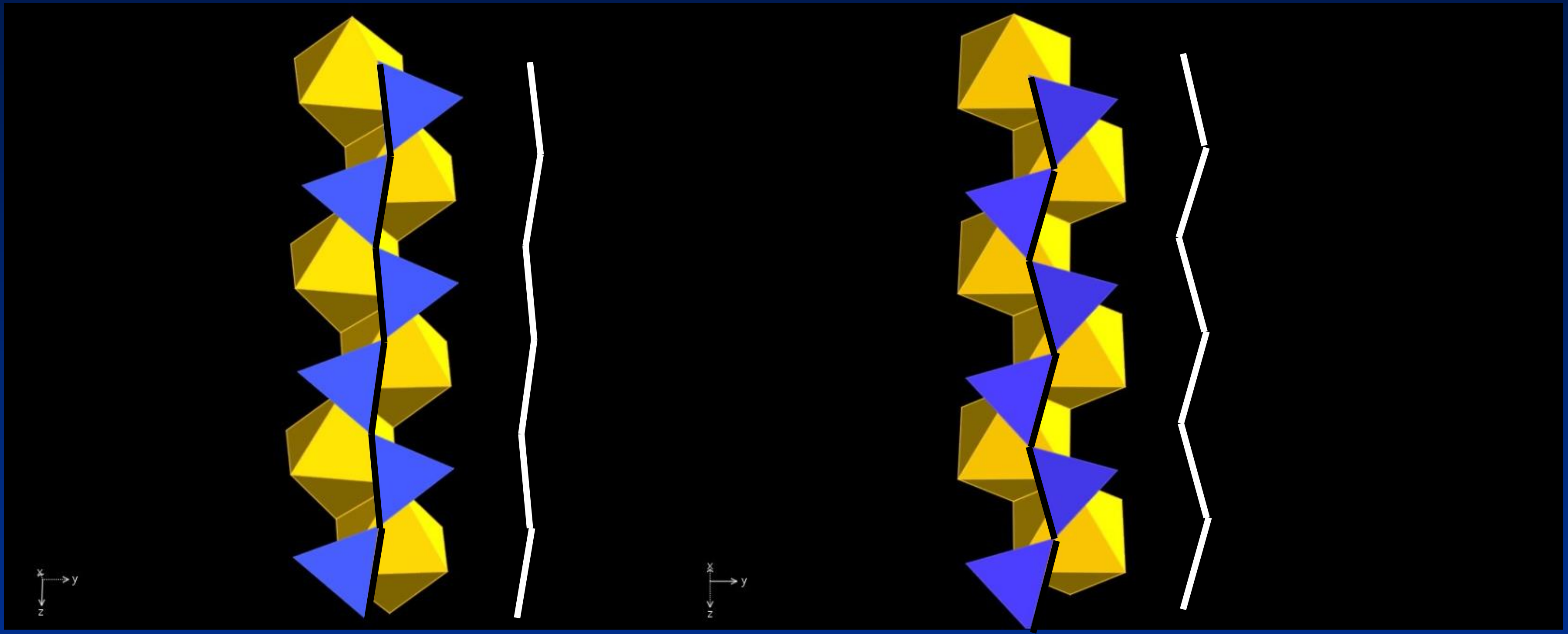


(010) section)



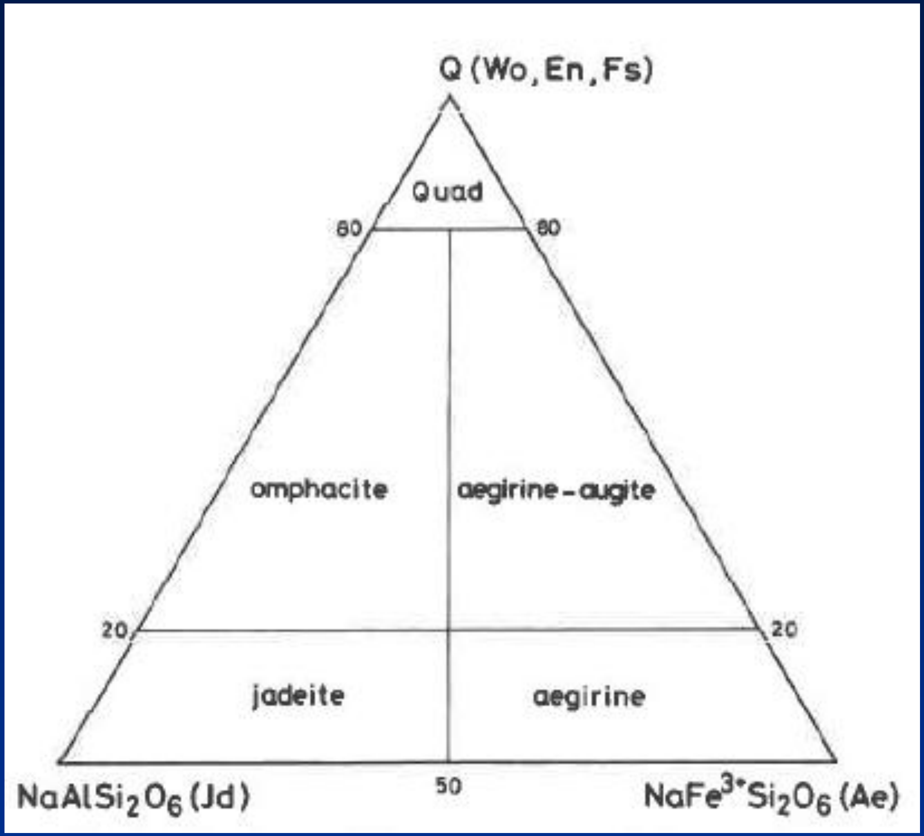
(010) section)

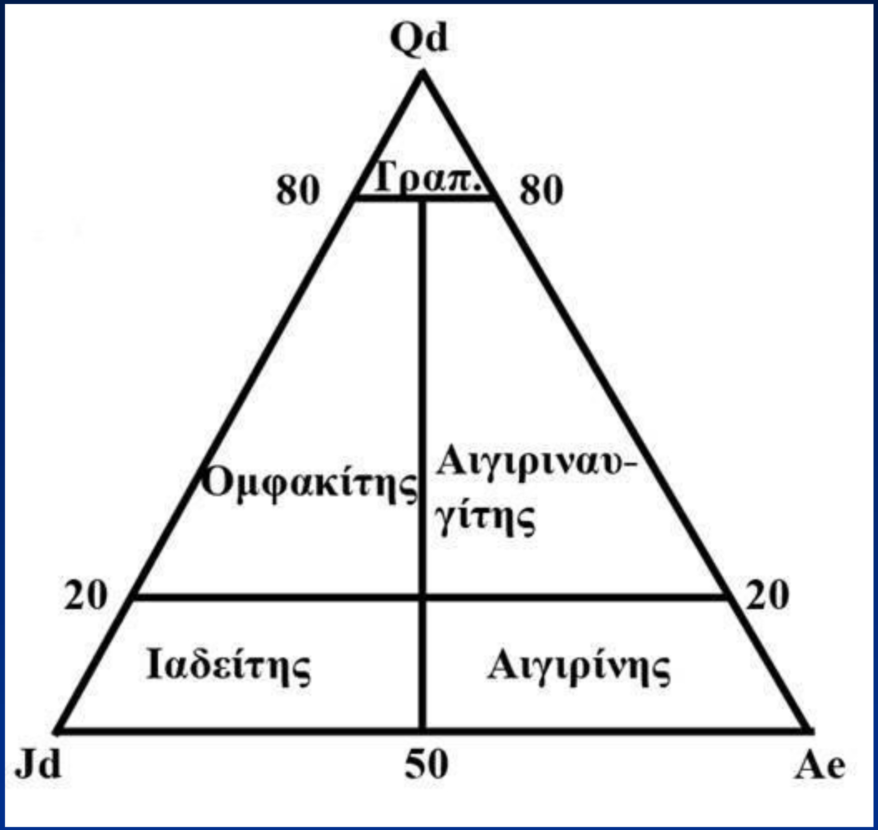
Mg,Fe,Ca-ΠΥΡΟΞΕΝΟΙ



$Ca^{2+}{}_{M2}$

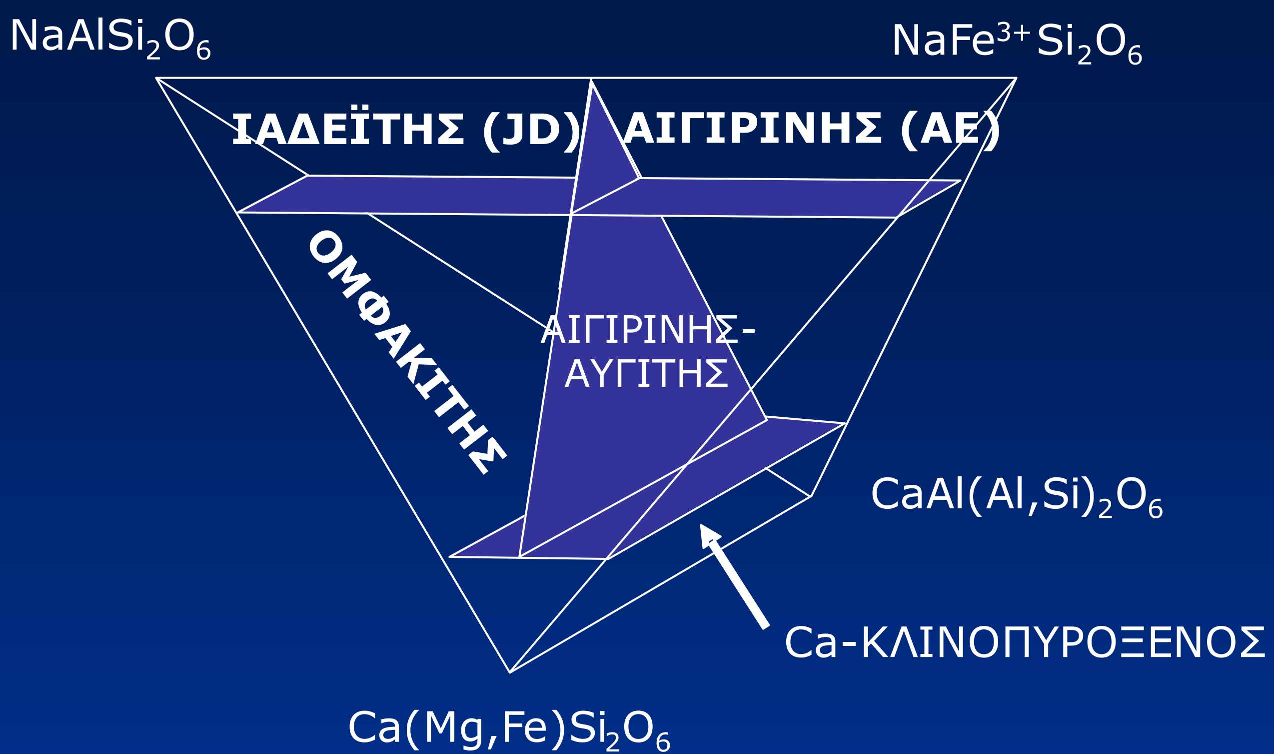
Na-ΠΥΡΟΞΕΝΟΙ



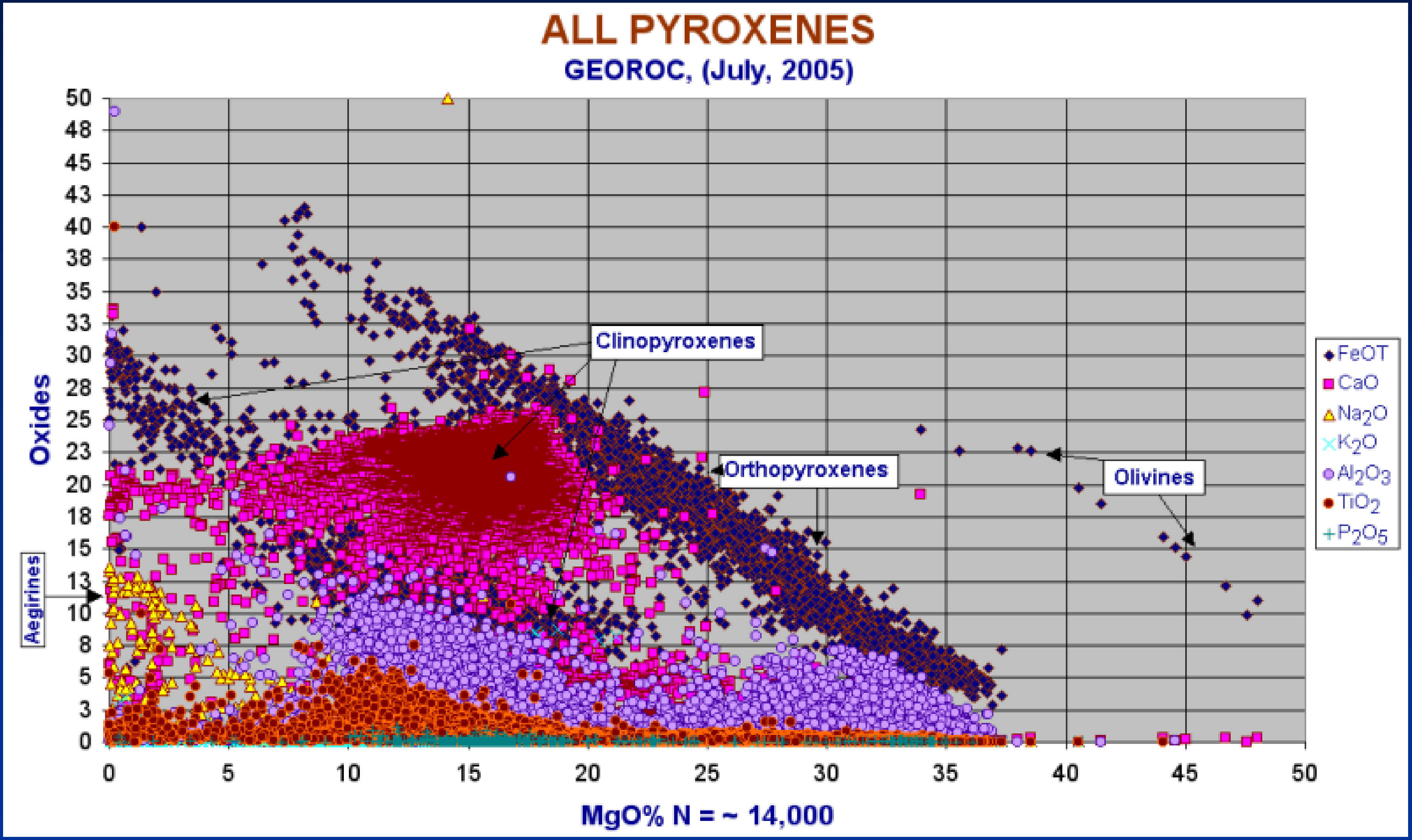


- $Qd = 100(Ca+Mg+Fe^{2+})/(Ca+Mg+Fe^{2+} + 2Na)$
- $Jd = 200Al*Na/(Al+Fe^{3+})*(Ca+Mg+Fe^{2+}+2Na)$
- $Ae = 200Fe^{3}+*Na/(Al+Fe^{3+})*\ Ca+Mg+Fe^{2+} + 2Na)$

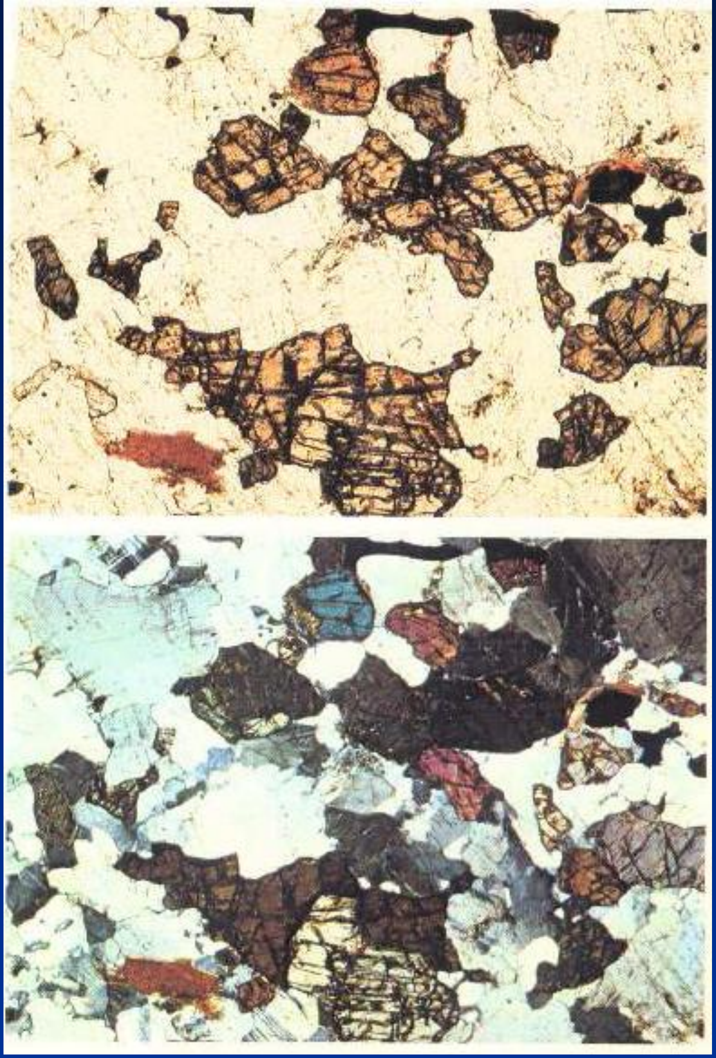
Na-ΠΥΡΟΞΕΝΟΙ



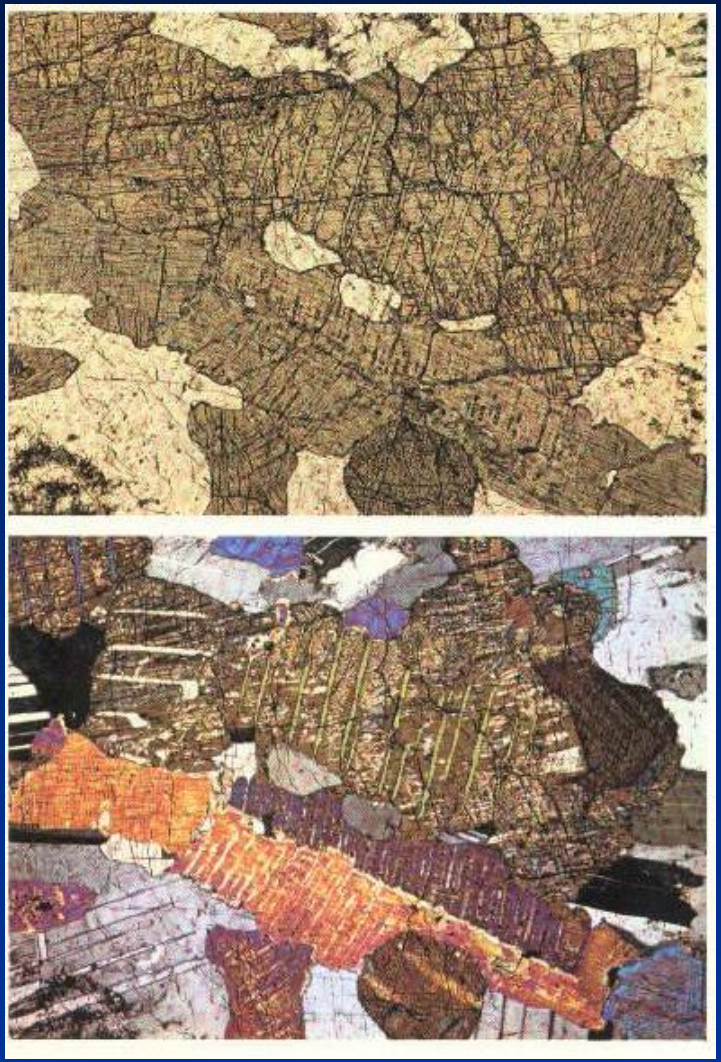
Σε πετρώματα HP οι πυρόξενοι εμπλουτίζονται σε Al^{3+} στη M_1 θέση ενώ κατιόντα Na^+ τοποθετούνται στην M_2 θέση. Σε T>700 ºC σχηματίζεται πλήρες στερεό διάλυμα μεταξύ Ιαδείτη και Αυγίτη ($Na^+_{M2} + Al^{3+}_{M1} \Leftrightarrow Ca^{2+}_{M2} + (Mg,Fe)^{2+}_{M1}$) ενώ σε χαμηλότερη T τα κατιόντα Na,Ca,Al,Mg αποκτούν τάξη και σχηματίζεται Ομφακίτης http://www.geokem.com/



ΠΥΡΟΞΕΝΟΙ

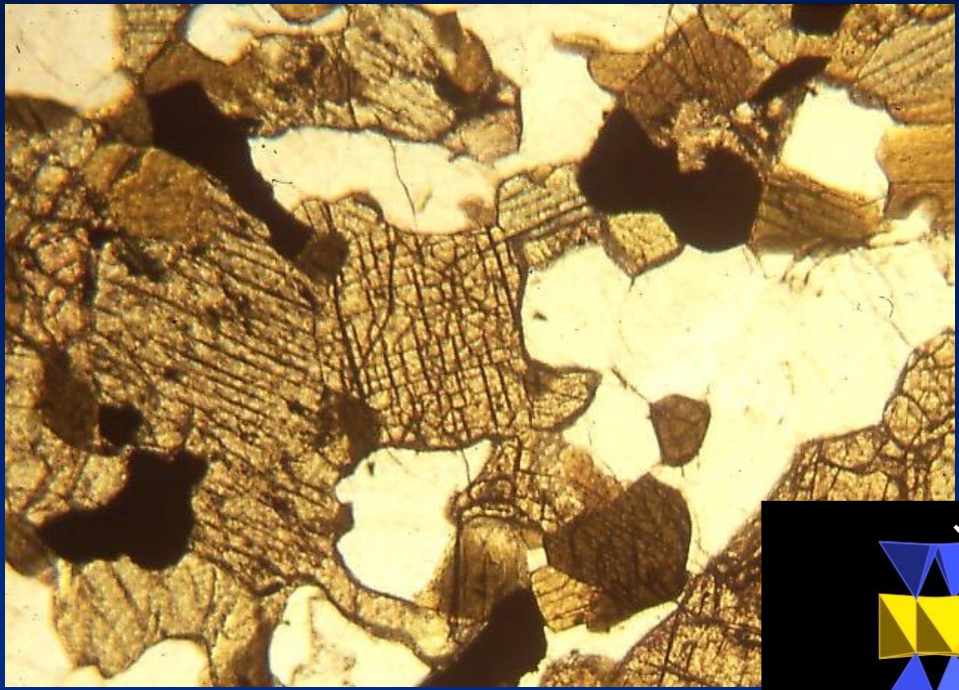


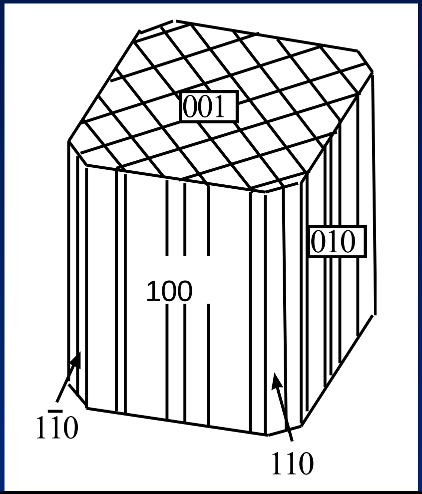
Ορθοπυρόξενοι

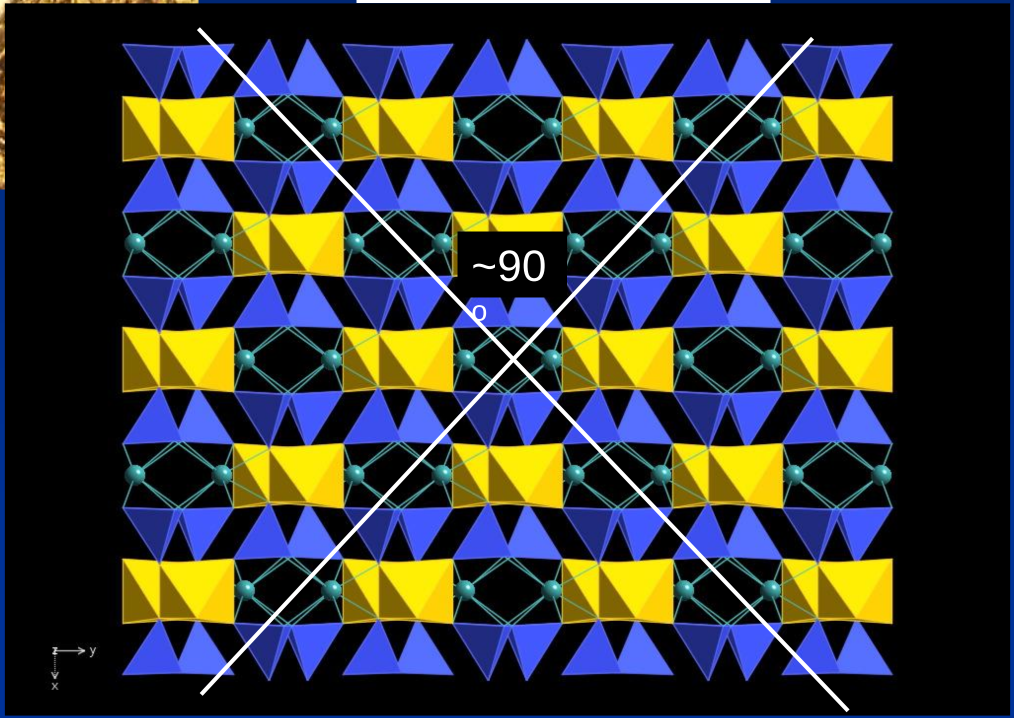


Ορθοπυρόξενοι - Κλινοπυρόξενοι

ΚΛΙΝΟΠΥΡΟΞΕΝΟΙ

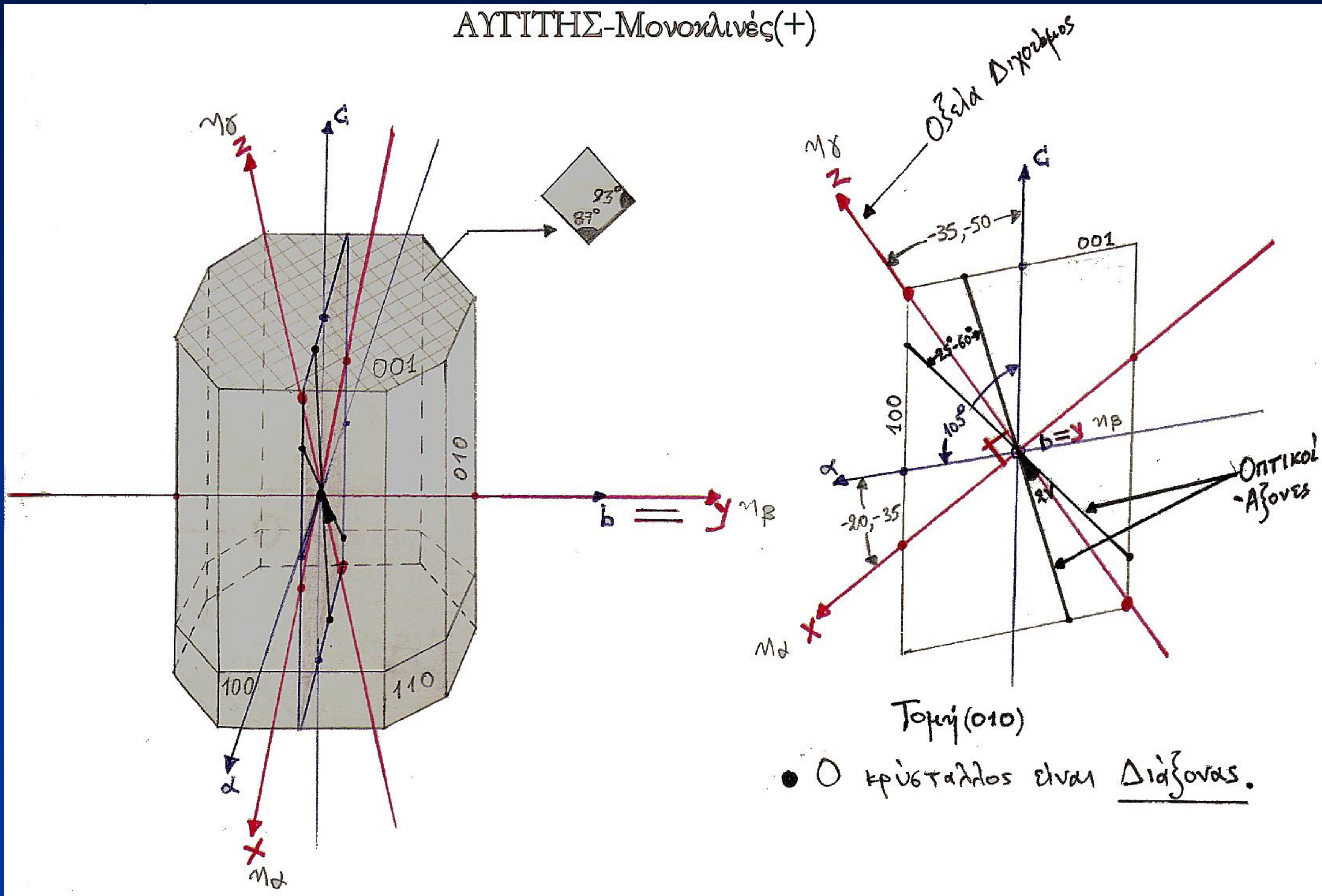






Σχισμός
κατά (110)

ΚΛΙΝΟΠΥΡΟΞΕΝΟΙ

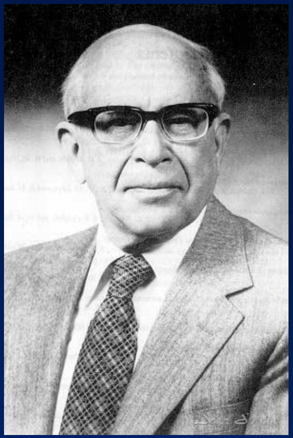


ΔΙΑΛΥΤΟΠΟΙΗΣΗ/ΑΠΟΣΑΘΡΩΣΗ ΟΡΥΚΤΩΝ ΚΑΙ ΠΥΡΟΞΕΝΩΝ

DISSOLUTION/WEATHERING OF MINERALS AND PYROXENES

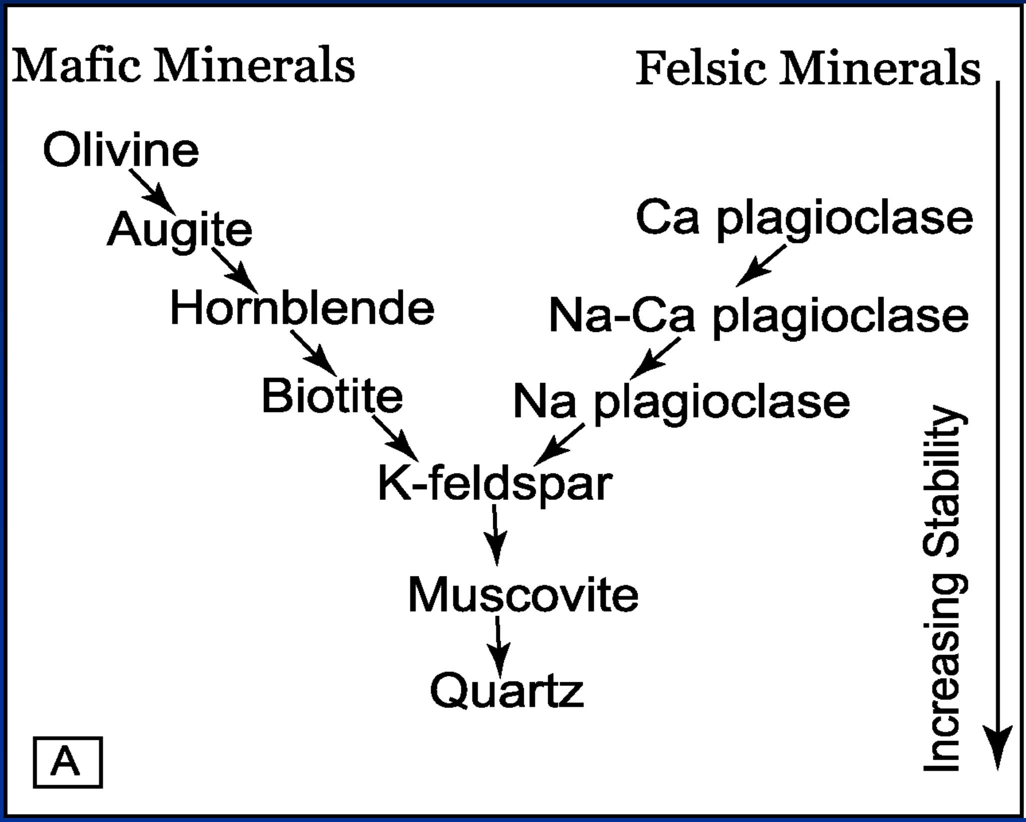
N.L. Bowen

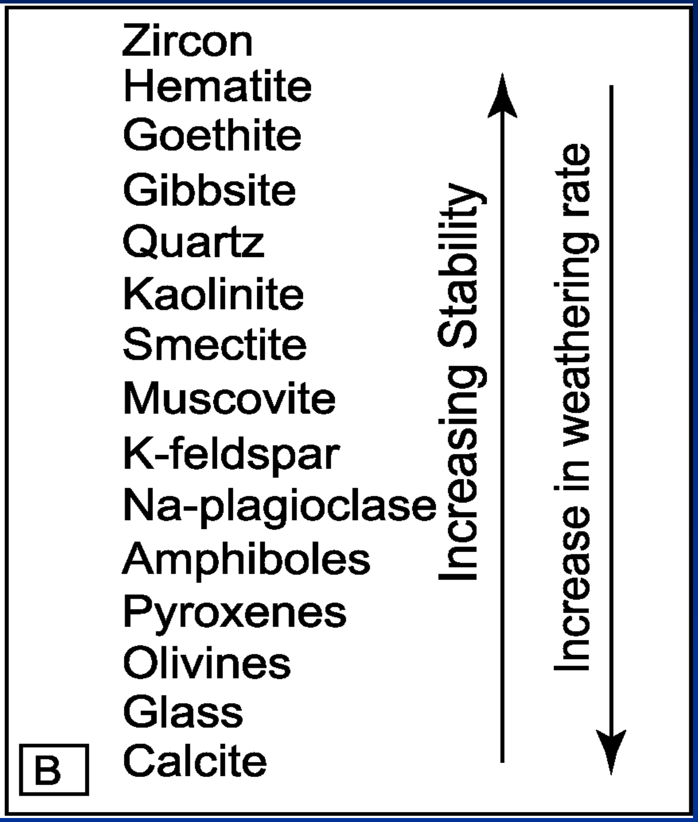
(1922)

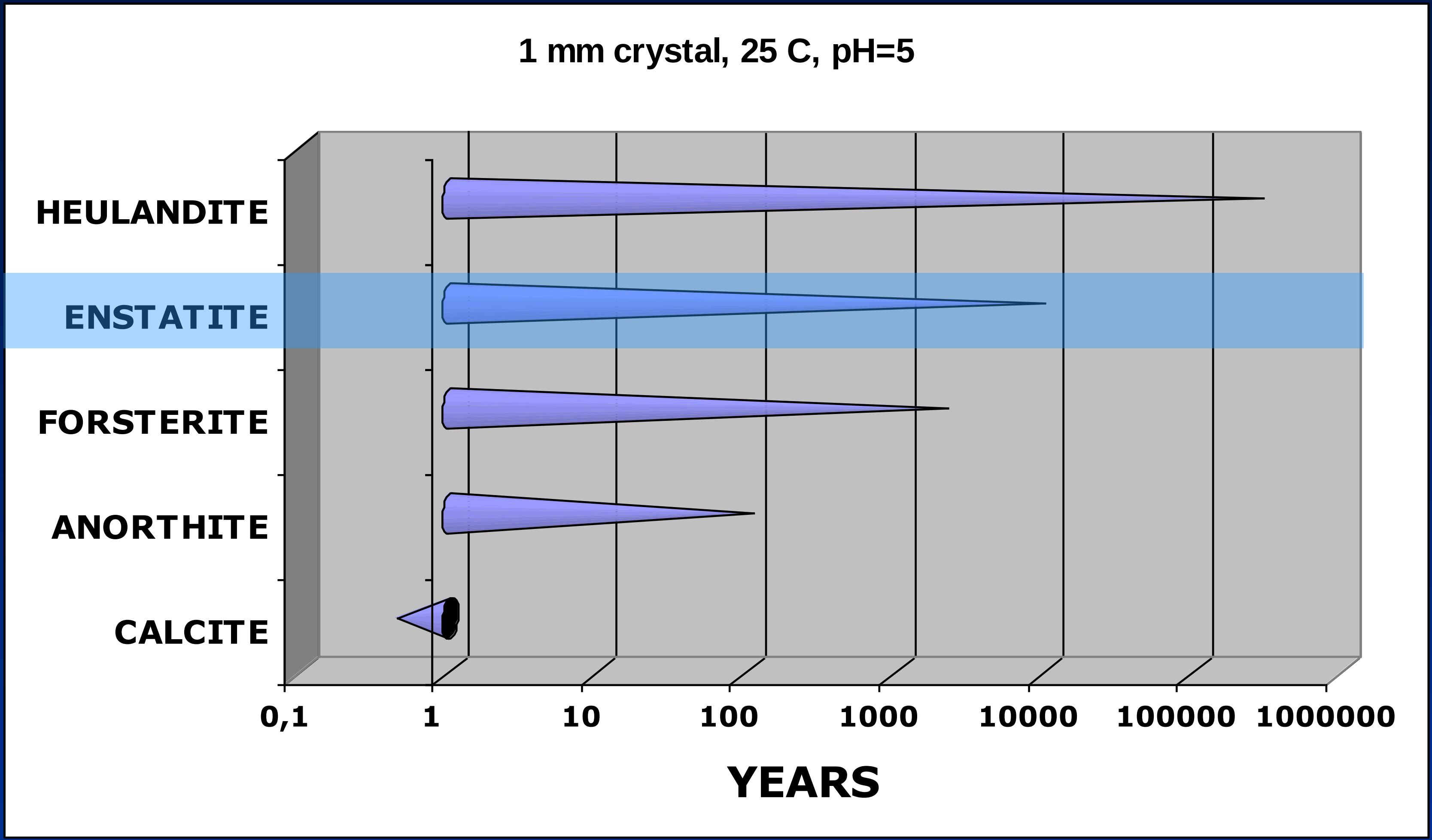


S. Goldich

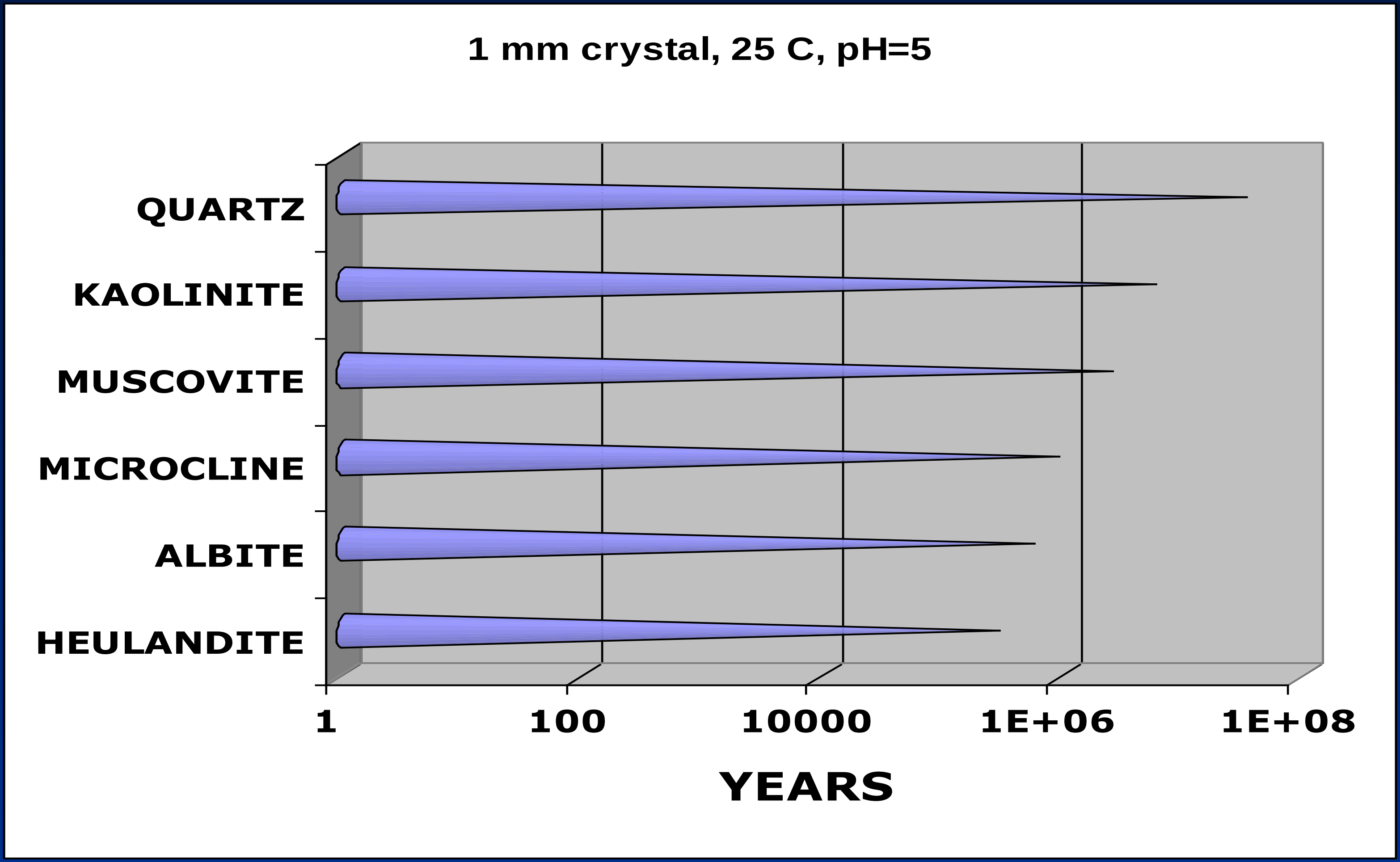
(1938)



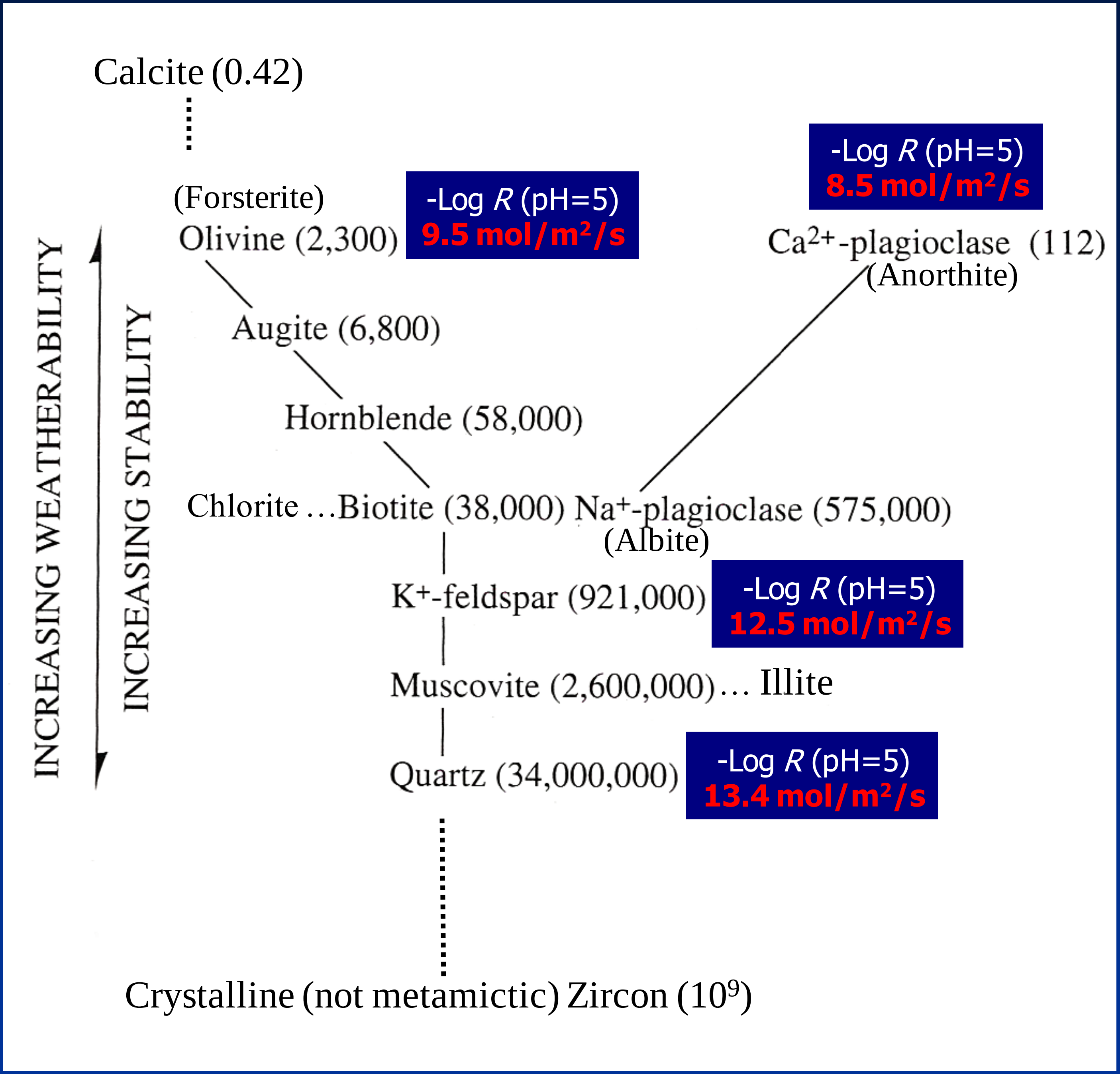




..... CALCITE : 150 days



QUARTZ : 34 000 000 yrs …..

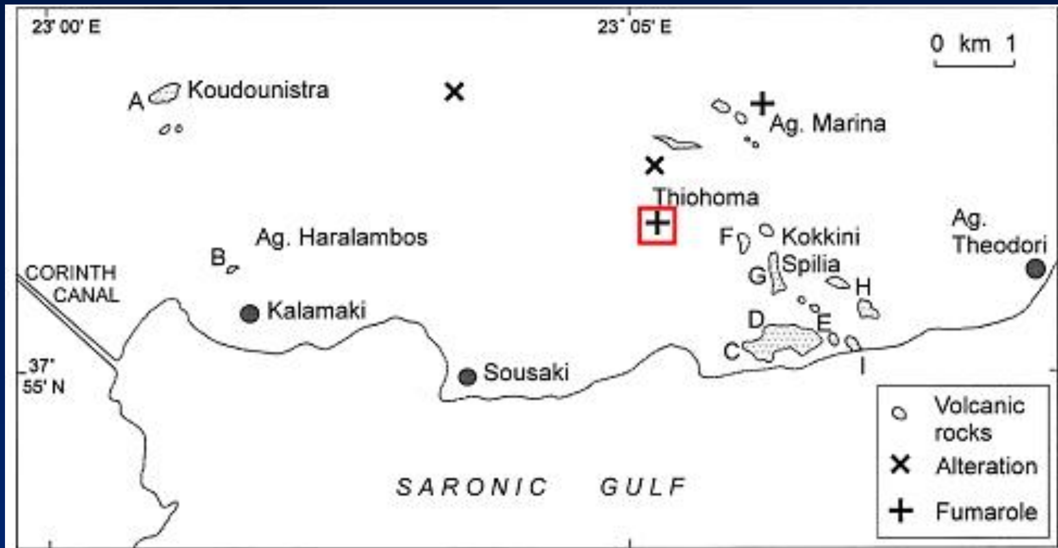


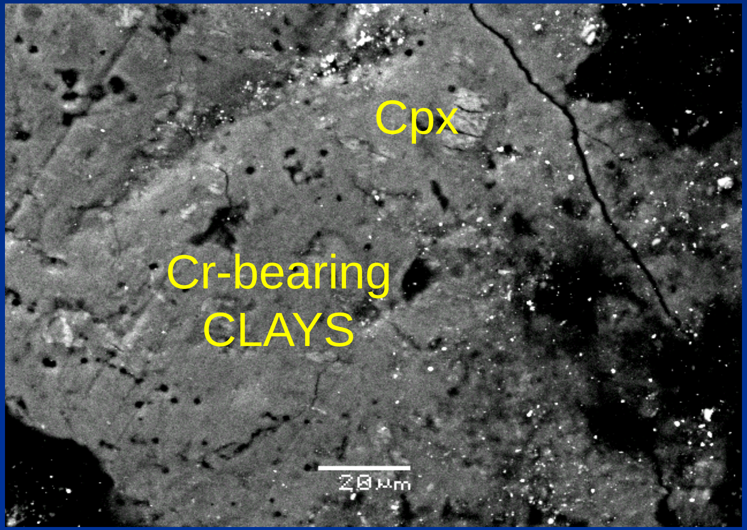
Calcite (0.42)
(Forsterite)
Olivine (2,300)
-Log R (pH=5)
9.5 mol/m²/s
-Log R (pH=5)
8.5 mol/m²/s
Ca2+-plagioclase (112)
(Anorthite)
Augite (6,800)
Hornblende (58,000)
Chlorite …Biotite (38,000) Na+-plagioclase (575,000)
(Albite)
K+-feldspar (921,000)
-Log R (pH=5)
12.5 mol/m²/s
Muscovite (2,600,000)… Illite
Quartz (34,000,000)
-Log R (pH=5)
13.4 mol/m²/s
Crystalline (not metamictic) Zircon (10^9)
INCREASING WEATHERABILITY
INCREASING STABILITY

Table 9-1. Partition Coefficients (C_S/C_L) for Some Commonly Used Trace Elements in Basaltic and Andesitic Rocks

		Olivine	**Opx**	**Cpx**	**Garnet**	**Plag**	**Amph**	**Magnetite**
Rb		0.010	0.022	0.031	0.042	0.071	0.29	
Sr		0.014	0.040	0.060	0.012	1.830	0.46	
Ba		0.010	0.013	0.026	0.023	0.23	0.42	
Ni		*14*	5	*7*	0.955	*0.01*	6.8	29
Cr		0.70	10	34	1.345	*0.01*	2.00	7.4
La	Rare Earth Elements	0.007	*0.03*	0.056	0.001	0.148	0.544	2
Ce		0.006	0.02	0.092	0.007	0.082	0.843	2
Nd		0.006	0.03	0.230	0.026	0.055	1.340	2
Sm		0.007	0.05	0.445	0.102	0.039	1.804	1
Eu		0.007	0.05	0.474	0.243	0.1/1.5*	1.557	1
Dy		0.013	0.15	0.582	1.940	0.023	2.024	1
Er		0.026	0.23	0.583	4.700	0.020	1.740	1.5
Yb		0.049	0.34	0.542	6.167	0.023	1.642	1.4
Lu		0.045	0.42	0.506	6.950	0.019	1.563	

Data from Rollinson (1993). * Eu^{3+}/Eu^{2+} *Italics* are estimated





Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

Institute for Synchrotron Radiation
Synchrotron Radiation Source ANKA

ΥΔΡΟΓΟΝΟ ΣΤΑ ΟΡΥΚΤΑ ΚΑΙ ΤΟΥΣ ΠΥΡΟΞΕΝΟΥΣ

(H^+-H_3O^+, OH^-, H_2O)

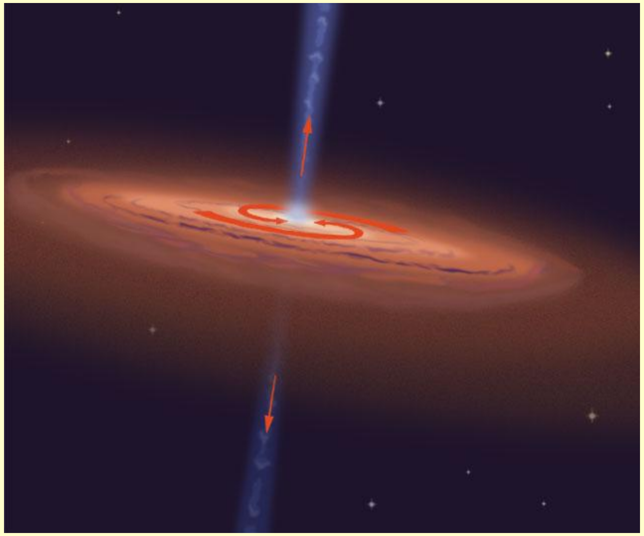
HYDROGEN IN MINERALS AND PYROXENES

Το H είναι **το πλέον διαδεδομένο χημικό στοιχείο στο Σύμπαν** ακολουθούμενο από το He, το O, τον C, το N, το Ne, το Mg, και το Si. Αποτελεί **βασικό συστατικό του DNA όλων των έμβιων όντων** ενώ ο μέσος όρος του H στο ανθρώπινο σώμα είναι ~10 wt%. Επομένως το H είναι άφθονο στην Βιόσφαιρα, και φυσικά στην Υδρόσφαιρα (ωκεανοί, λίμνες, ποταμοί, κ.λ.π.). Στην Ατμόσφαιρα το H είναι λιγότερο διαδεδομένο (~0.53 ppm), ενώ στον **στερεό φλοιό της Γής** (ωκεάνειο και ηπειρωτικό) υπολογίζεται σε **~0.14 wt% (~1400 ppm)** κατά μέσο όρο.

Είναι φανερό ότι ενώ τεράστια ποσά Η είναι διαθέσιμα στην Υδρόσφαιρα, δεν συμβαίνει το ίδιο και στην Λιθόσφαιρα όπου το Η απαντά *κυρίως* στα λεγόμενα **“ένυδρα” ορυκτά** (Nominally Hydrous Minerals – **NHM**) των πετρωμάτων. Αξίζει να σημειωθεί ότι ενώ **οι ωκεανοί αποτελούν το 71% της επιφάνειας του πλανήτη αντιπροσωπεύουν μόνο το 0.025% της ολικής μάζας**, και συνεπώς πολλά ερωτήματα παραμένουν για το τι ακριβώς συμβαίνει με **το Η στο υπόλοιπο 99.975% της μάζας της Γής (φλοιός-<u>μανδύας</u>-πυρήνας)**.

ΚΟΣΜΟΧΗΜΙΚΕΣ ΠΗΓΕΣ (πιθανώς <10% συμβολή από SN)

Ηλιακό Νεφέλωμα (Solar Nebula-SN)



H_2 : 96.1 %
He : 3.8 %
CO : 0.077 %
Ne : 0.016 %
N_2 : 78 ppm
$H_2O/H_2 \sim 10^{-4}$

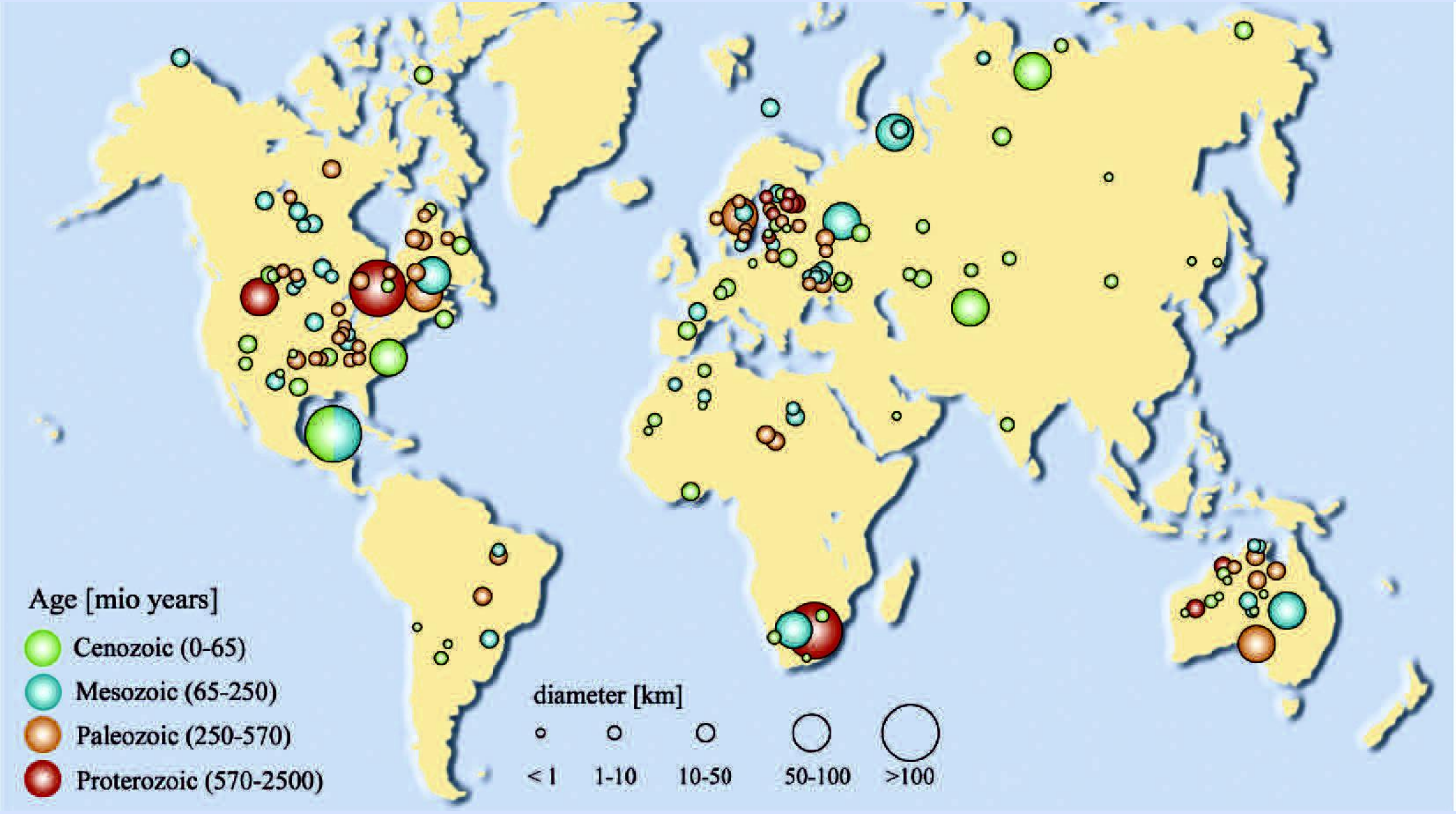
Κομήτες

έως και
50%
H_2O

Μετεωριτική Ύλη

έως και
10%
H_2O
σε ανθρακικούς
ΧΟΝΔΡΙΤΕΣ

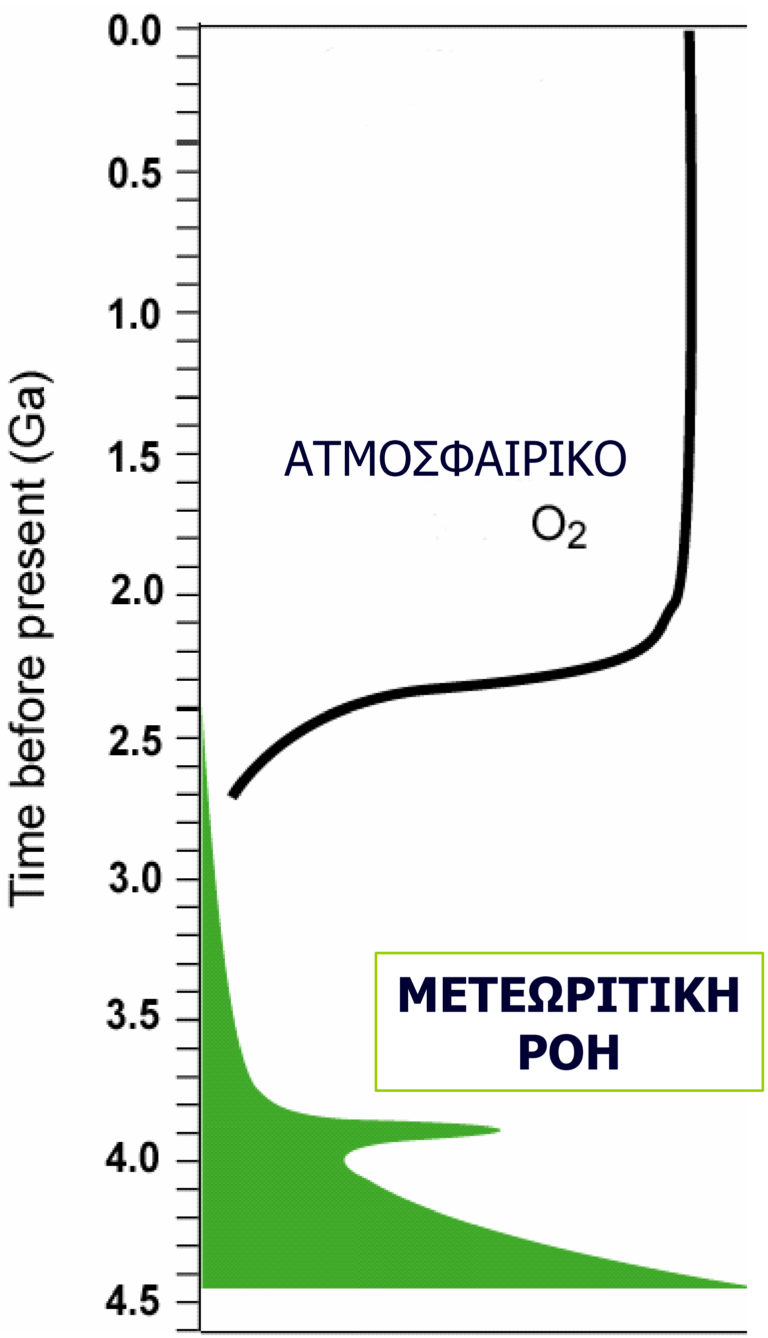
Μετεωριτικοί Κρατήρες

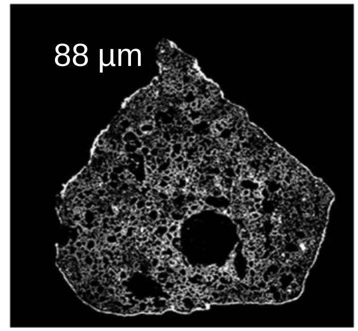


ΡΟΗ ΥΛΗΣ ΣΕ ΓΗΙΝΟΥΣ ΠΛΑΝΗΤΕΣ

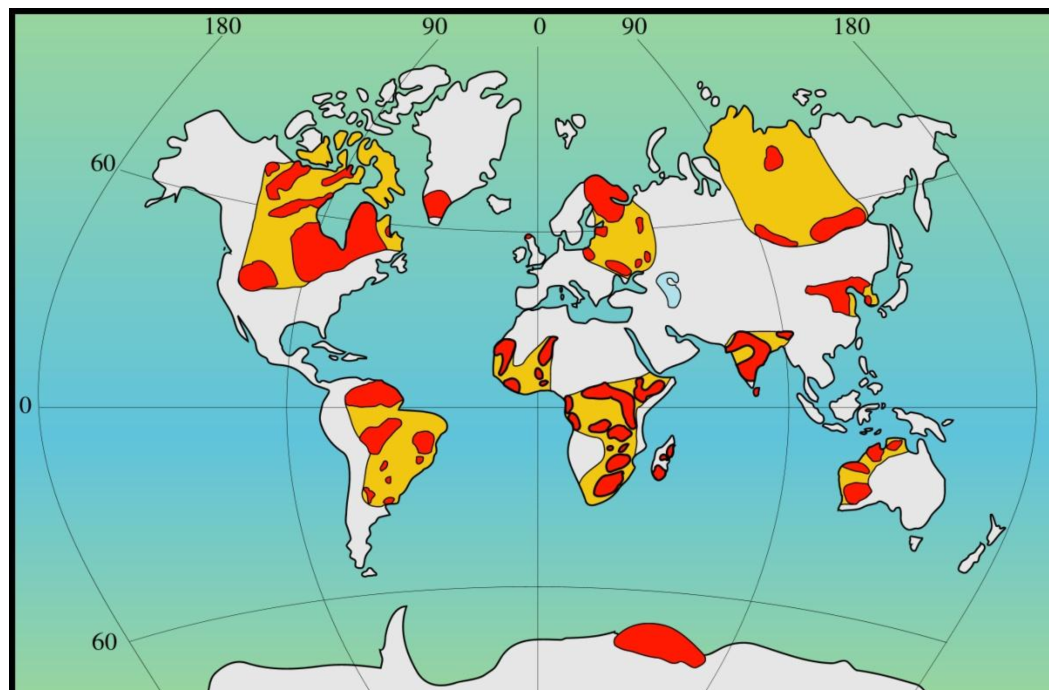
IDPs, MM : 20,000 – 40,000 tons/yr

Μετεωρίτες : 10 tons/yr

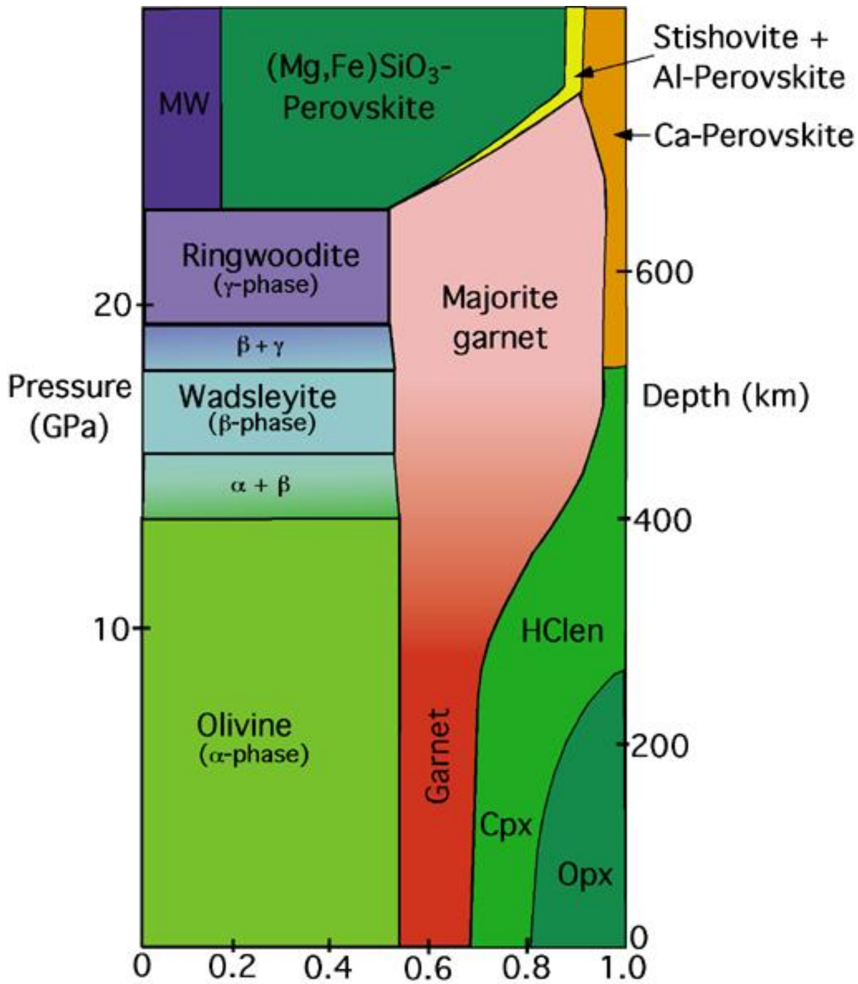


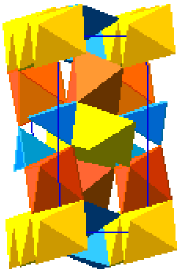


ΜΙΚΡΟ-ΜΕΤΕΩΡΙΤΕΣ (MM)



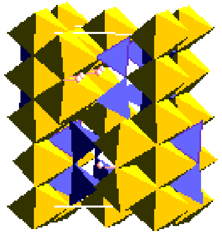
ΠΟΛΥΜΟΡΦΙΣΜΟΣ ΤΟΥ ΟΛΙΒΙΝΗ (κατ' όνομα "άνυδρο" πυριτικό ορυκτό) ΣΤΟ ΕΣΩΤΕΡΙΚΟ ΤΗΣ ΓΗΣ





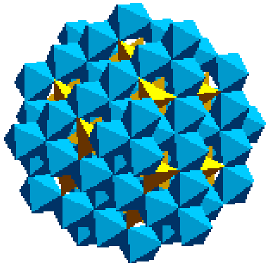
α-$(Mg,Fe)_2SiO_4$
ΡΟΜΒΙΚΟ

410 Km

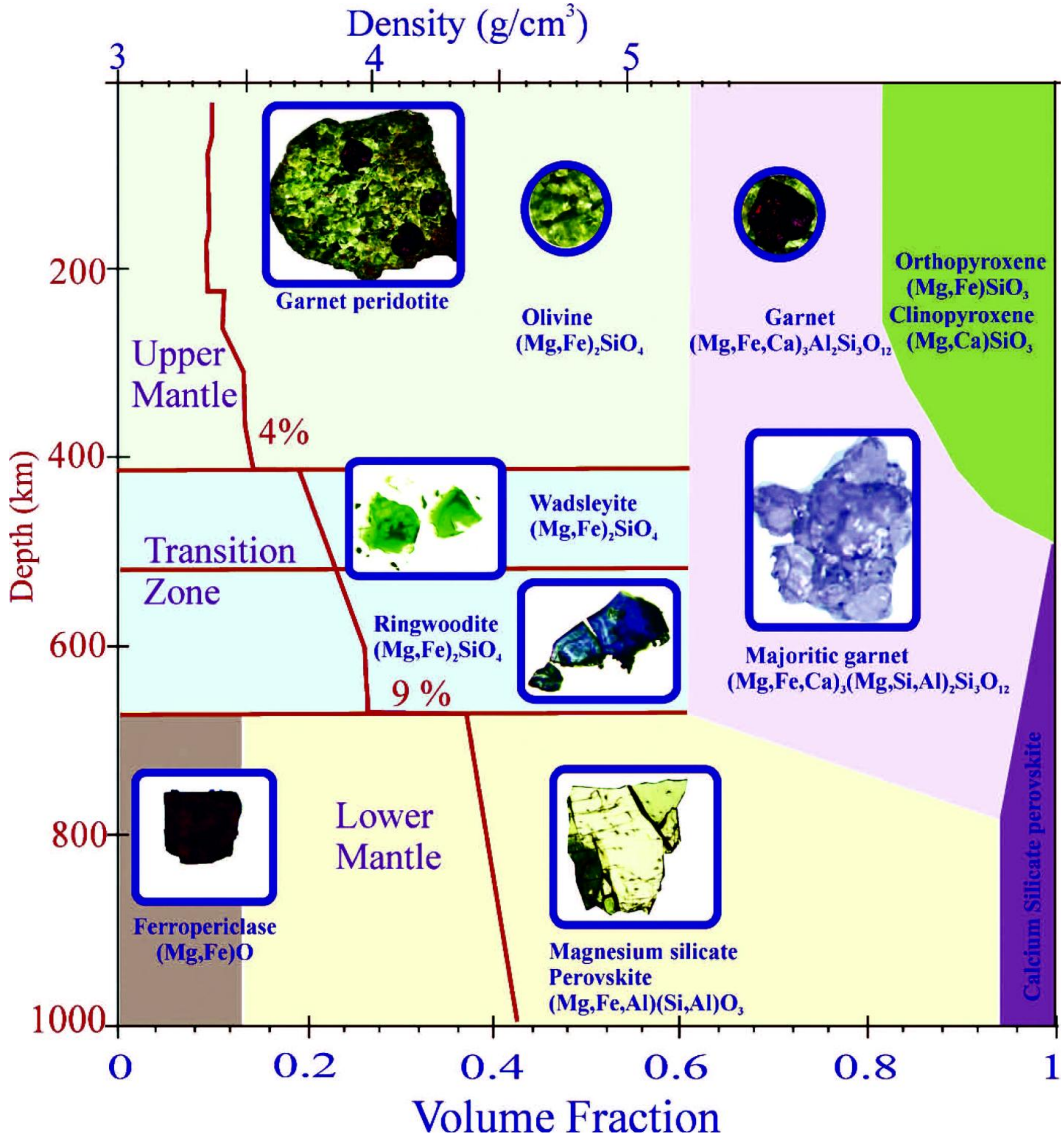


β-$(Mg,Fe)_2SiO_4$
ΡΟΜΒΙΚΟ
Γουαντσλεϊτης

520 Km



γ-$(Mg,Fe)_2SiO_4$
ΚΥΒΙΚΟ
Ρινγκουντίτης

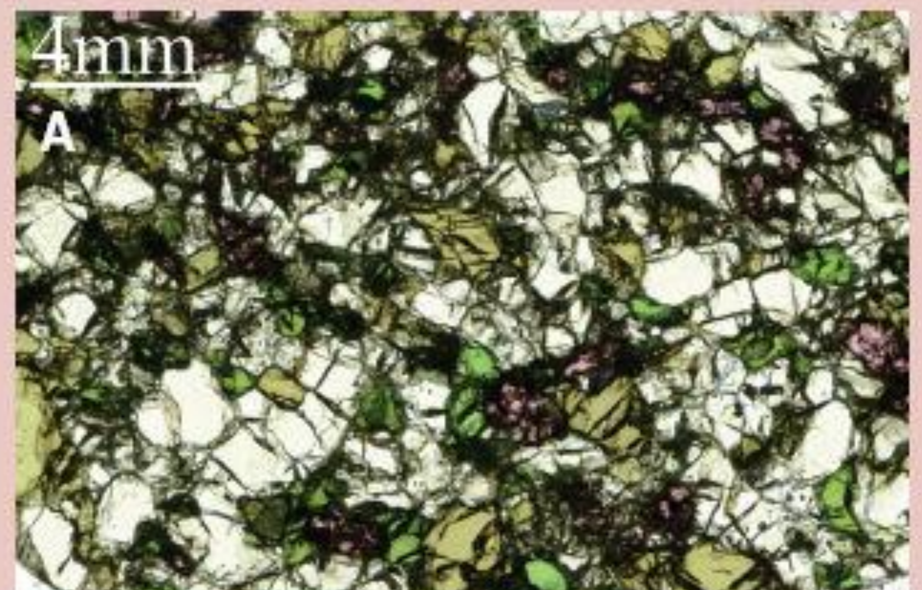


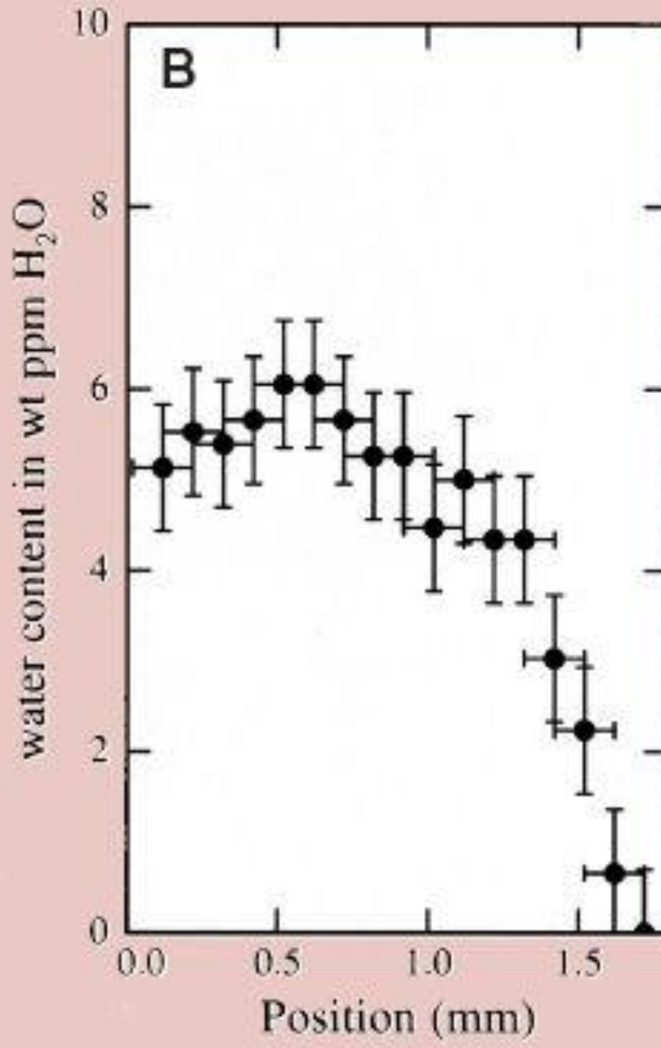
Density (g/cm³)
3
4
5
200
400
600
800
1000
Depth (km)
Garnet peridotite
Olivine
(Mg,Fe)₂SiO₄
Garnet
(Mg,Fe,Ca)₃Al₂Si₃O₁₂
Orthopyroxene
(Mg,Fe)SiO₃
Clinopyroxene
(Mg,Ca)SiO₃
Upper
Mantle
4%
Wadsleyite
(Mg,Fe)₂SiO₄
Transition
Zone
Ringwoodite
(Mg,Fe)₂SiO₄
9 %
Majoritic garnet
(Mg,Fe,Ca)₃(Mg,Si,Al)₂Si₃O₁₂
Calcium Silicate perovskite
Lower
Mantle
Ferropericlase
(Mg,Fe)O
Magnesium silicate
Perovskite
(Mg,Fe,Al)(Si,Al)O₃
0
0.2
0.4
0.6
0.8
1
Volume Fraction

BGI

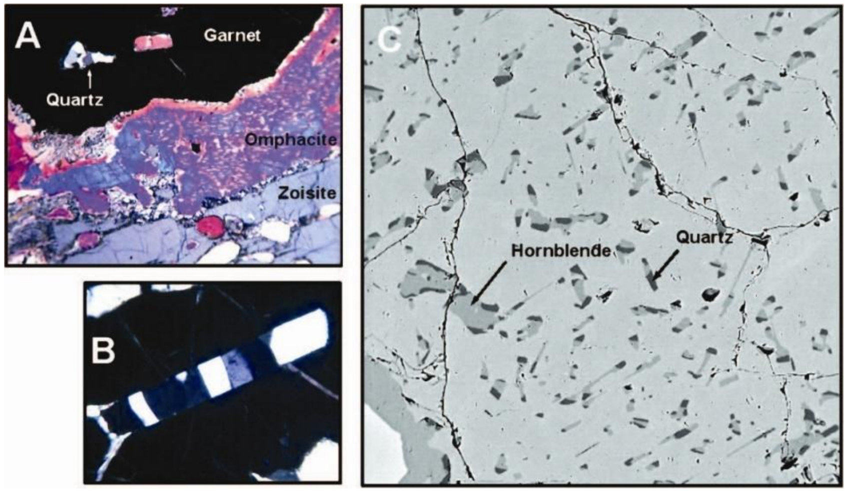
Bayerisches
Geoinstitut

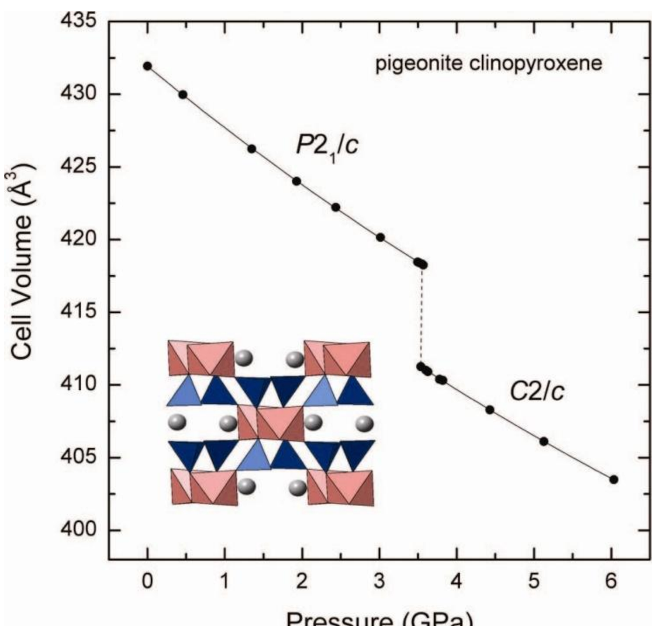
Fig. 6.4: (A) Photomicrograph of a garnet-bearing lherzolite xenolith from the Pali-aike volcanic field (Chilean Patagonia). FTIR spectra obtained from large olivine crystals (colourless) reveal hydrogen depletion towards olivine rims and the development of hydrogen diffusion profiles (B). These diffusion profiles provide direct evidence of dehydration of mantle samples via hydrogen diffusion during transport into the crust.





UHP ΠΥΡΟΞΕΝΟΙ





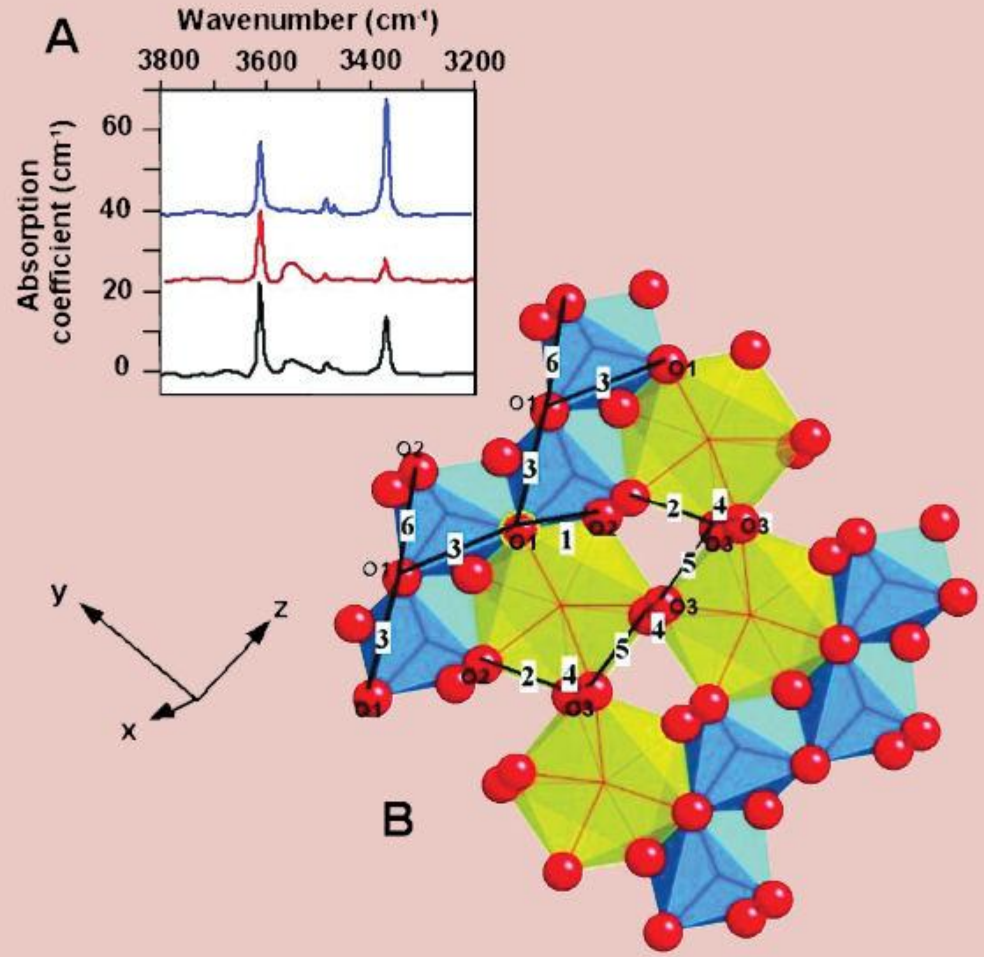
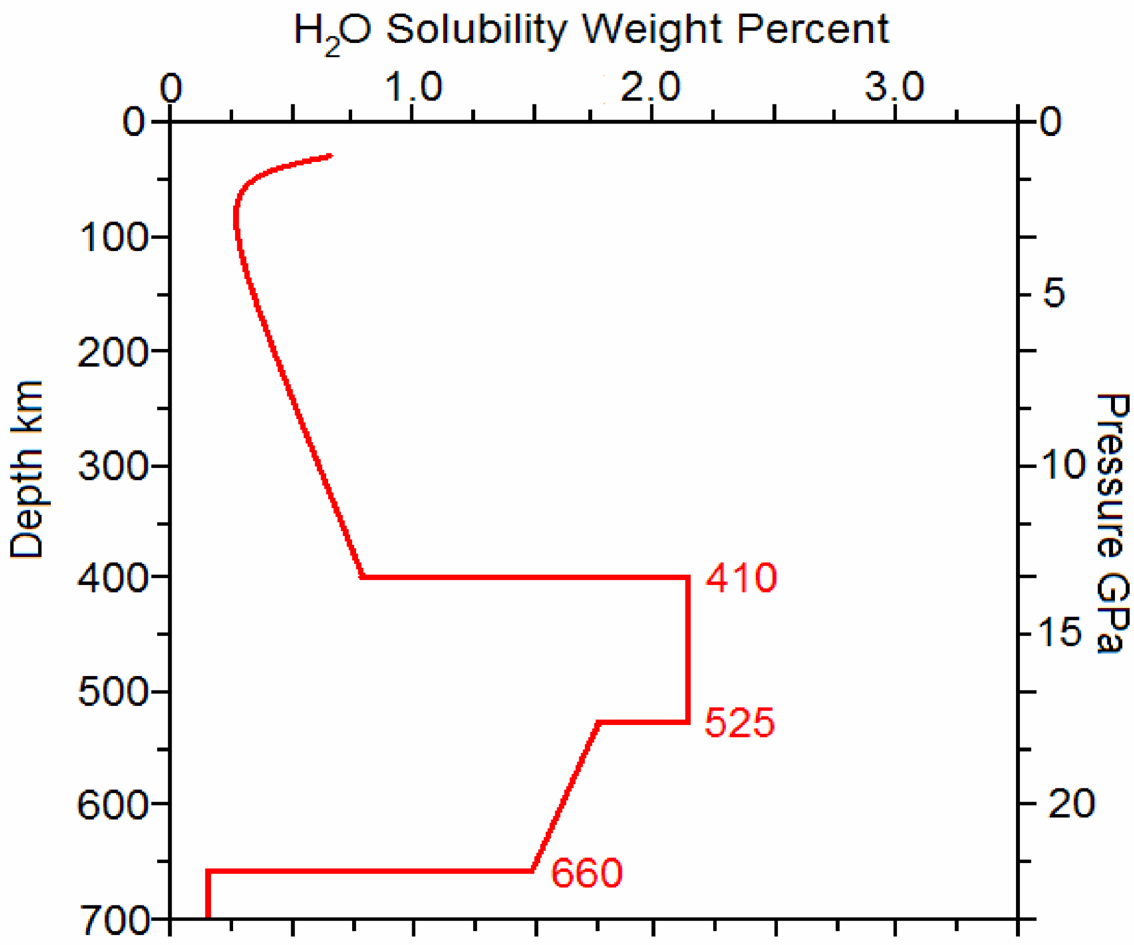
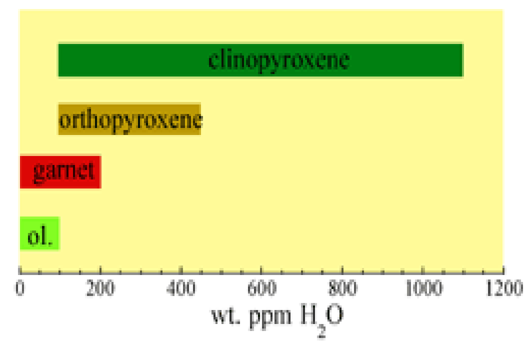
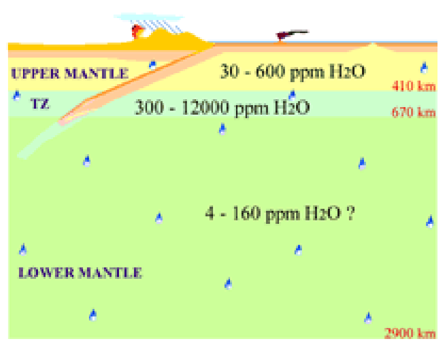


Fig. 6.5: Results from investigation of H incorporation and water solubility in synthetic jadeite. (A) FTIR spectra for water-saturated jadeite synthesised at 3.0 GPa, 600°C (black = unpolarised, red = radiation polarised perpendicular to *c* axis, blue = radiation polarised parallel to *c* axis). Peaks in the spectra imply absorption of radiation due to vibration of OH dipoles, indicating that H is present in the structure, associated with specific oxygen sites. (B) Representation of part of the jadeite structure showing mechanisms for H incorporation consistent with data from FTIR spectra. Model shows octahedral sheet (yellow = *M2* sites, blue = *M1* sites, red spheres = oxygen sites). Numbers refer to possible H incorporation mechanisms.

Κατανομή του H (ως H_2O) στο εσωτερικό της Γής και σε διάφορα κατ’ όνομα “άνυδρα” πυριτικά ορυκτά (Nominally Anhydrous Minerals - **NAM**)







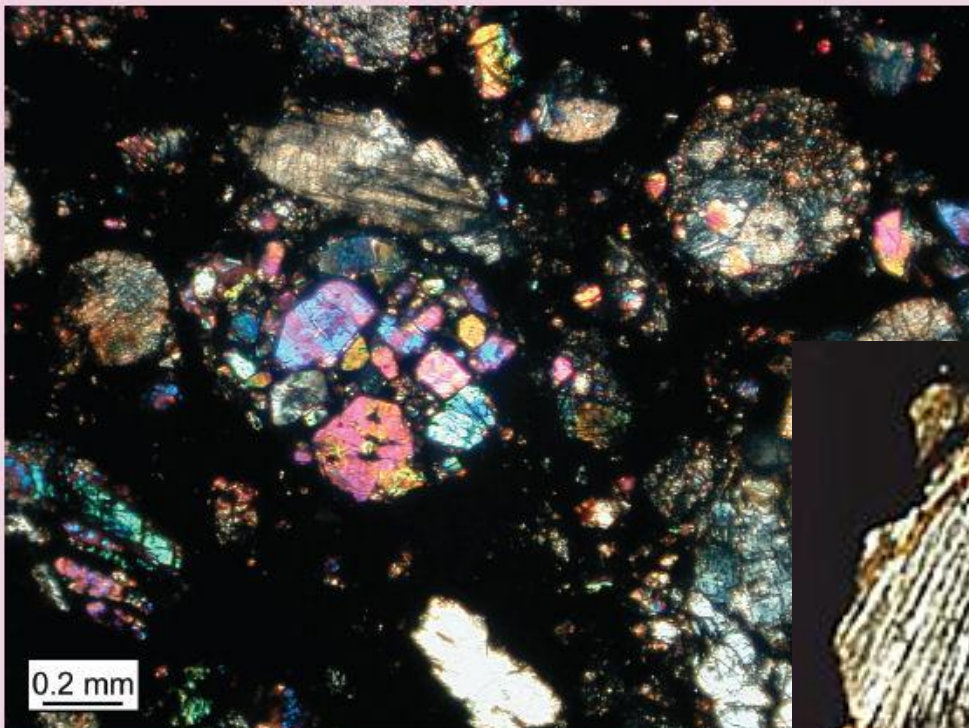
Water Solubility in Aluminous Orthopyroxene and the Origin of Earth's Asthenosphere

Katrin Mierdel,[1] Hans Keppler,[1,2]* Joseph R. Smyth,[2,3] Falko Langenhorst[2,4]

Plate tectonics is based on the concept of rigid lithosphere plates sliding on a mechanically weak asthenosphere. Many models assume that the weakness of the asthenosphere is related to the presence of small amounts of hydrous melts. However, the mechanism that may cause melting in the asthenosphere is not well understood. We show that the asthenosphere coincides with a zone where the water solubility in mantle minerals has a pronounced minimum. The minimum is due to a sharp decrease of water solubility in aluminous orthopyroxene with depth, whereas the water solubility in olivine continuously increases with pressure. Melting in the asthenosphere may therefore be related not to volatile enrichment but to a minimum in water solubility, which causes excess water to form a hydrous silicate melt.

Earth's asthenosphere is often assumed to roughly coincide with the low-velocity zone, a layer of reduced seismic velocities and increased attenuation of seismic waves. The low-velocity zone usually begins at a depth of 60 to 80 km below the oceans and ends around 220 km (*1*). Below continental shields, the upper boundary is depressed to 150 km. The seismic characteristics of the low-velocity zone could be easily explained by the presence of a small frac-

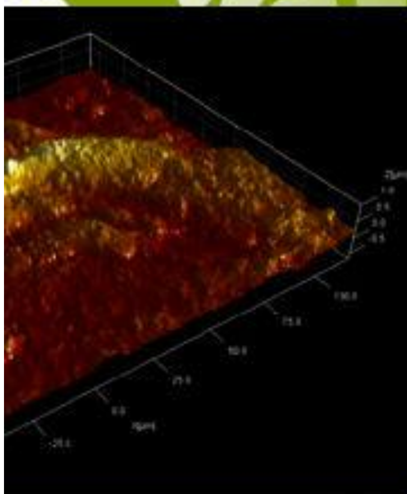
Fig. 1.3: Optical photomicrograph (crossed polarisers) of a carbonaceous chondrite with numerous chondrules (spheres) embedded in a dark, fine-grained matrix that contains organic matter. The chondrules display various textures and are composed of olivine, pyroxene and glass.



ΠΥΡΟΞΕΝΟΙ
σε
ΧΟΝΔΡΙΤΕΣ

Tsukamoto Lab.

Department of Earth and Planetary Materials Science
Graduate School of Science, Tohoku University



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Publication
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