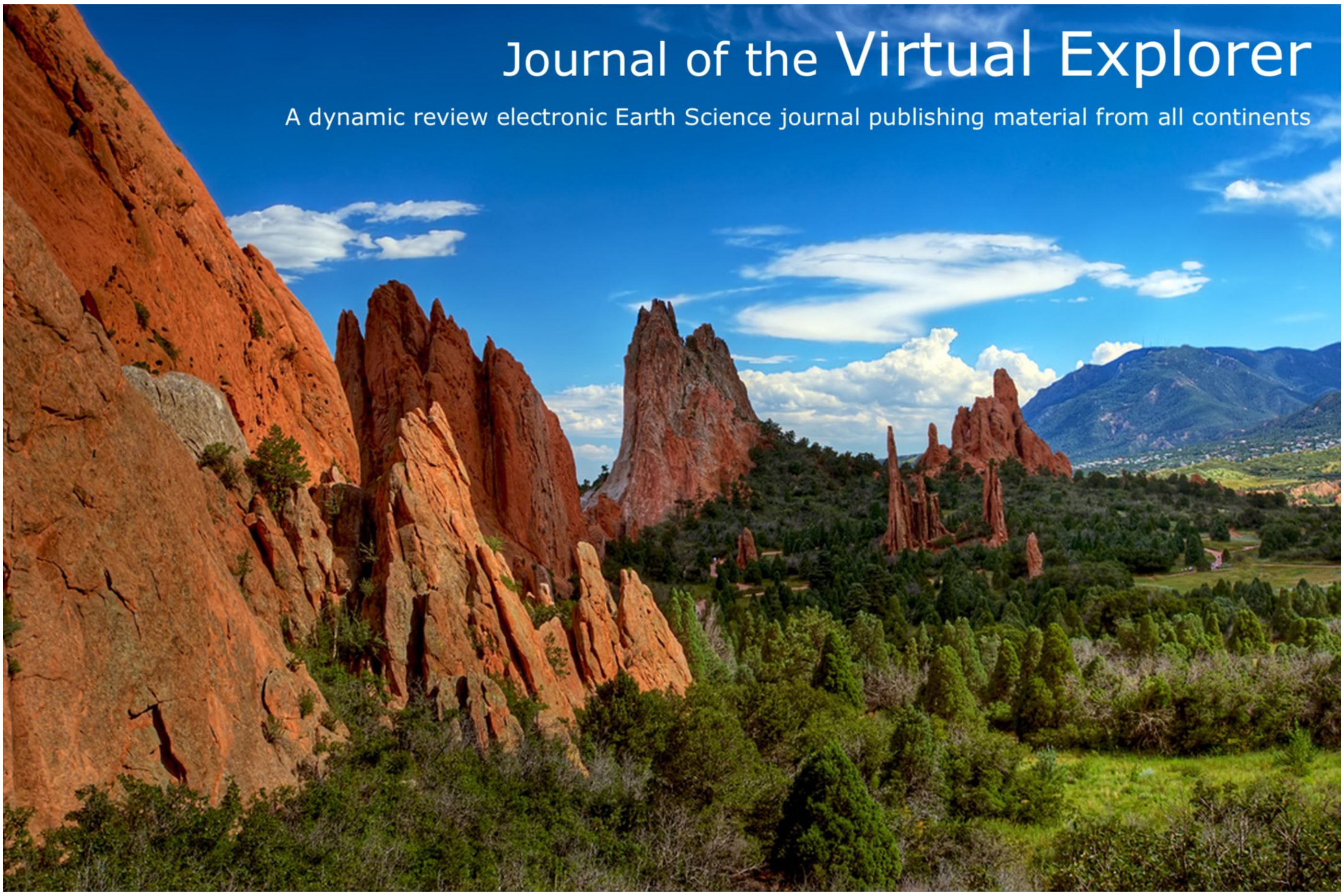


Detrital zircon U-Pb data from the Hellenic south Aegean belts: Constraints on the age and source of the South Aegean basement

Antonios E. Marsellos, David A. Foster, G. D. Kamenov, K. Kyriakopoulos

Journal of the Virtual Explorer, Electronic Edition, ISSN 1441-8142, volume **42**, paper 3
In: (Eds.) Emmanuel Skourtsos and Gordon S. Lister, The Geology of Greece, 2012.

Detrital zircon U-Pb data from the Hellenic south Aegean belts: Constraints on the age and source of the South Aegean basement

Antonios E. Marsellos
Dept. of Geological Sciences, University of Florida, Gainesville, FL 32611, U.S.A. *Email: amars@ufl.edu*

David A. Foster
Dept. of Geological Sciences, University of Florida, Gainesville, FL 32611, U.S.A.

G. D. Kamenov
Dept. of Geological Sciences, University of Florida, Gainesville, FL 32611, U.S.A.

K. Kyriakopoulos
Dept. of Geology & Geoenvironment, National & Kapodistrian University of Athens, Panepistimioupolis, Greece, GR 12308, E.U.

Abstract: U-Pb analyses of 595 zircons from 10 metasedimentary rocks collected from the forearc and volcanic arc in the South Aegean, Greece constrain the provenance of the widespread Phyllite-Quartzite unit (PQU) above the retreating Hellenic subduction zone in the South Aegean. Zircons from Miocene metamorphic rocks in the forearc on the islands of Peloponnese, Kythera, and Crete all give pre-Cenozoic U-Pb crystallization ages. Metamorphic rocks exposed within the volcanic arc on Milos and Santorini also lack zircons grown during the recent phase of Hellenic subduction. Samples of clastic sedimentary rocks that were affected by the Miocene metamorphism show zircon crystallization ages that range from *ca.* 80 to 2937 Ma. Sandstone collected from the upper plate of the Kythera Detachment fault, which was not affected by Miocene metamorphism based on Jurassic-Cretaceous zircon fission-track data, yields detrital zircon ages that range from *ca.* 202 to 3487 Ma. Zircons with Archean crystallization ages are absent in the metamorphosed detrital rocks from Crete, Kythera, Peloponnese, Milos and Santorini. This is most likely because metamorphism caused the breakdown and/or recrystallization of any ancient zircons with substantial radiation damage. Mean U-Pb ages ($^{206}Pb/^{238}U$ or $^{207}Pb/^{206}Pb$) of distinct populations of 534 concordant zircons are about 316, 639, 994, 1954, 2598 and 3325 Ma. These populations are consistent with parts of the detritus that now makes up the South Aegean basement having a source within orogenic belts of North African or other parts of Gondwana.

Citation: 2012. Detrital zircon U-Pb data from the Hellenic south Aegean belts: Constraints on the age and source of the South Aegean basement. In: (Eds.) Emmanuel Skourtsos and Gordon S. Lister, *Journal of the Virtual Explorer*, volume **42**, paper 3, doi: 10.3809/jvirtex.2011.00284

Introduction

The South Aegean forearc ridge, the Hellenic Arc, known also as the Peloponnese-Cretan ridge, separates the 3000 to 5000 m deep Hellenic "trench" to the southwest from the 1000 to 2000 m deep Cretan Sea basin to the northeast (Fig. 1). The large-scale internal structure of the Hellenic forearc ridge developed during the late Eocene-early Miocene in response to the collision of the Apulia microcontinent (attached to the African plate). At present only parts of the Apulia are exposed as most of it was subducted and/or accreted against the active European continental margin (the Pelagonian "terrane") (Thomson and others, 1998). The sedimentary cover of Apulia is mostly represented by the rocks of the Phyllite-Quartzites unit (PQU) and the Tripolitza unit (recrystallized limestone), which are exposed over wide areas on the Peloponnese-Cretan ridge. In this study we apply U-Pb dating of detrital zircons from the PQU and inherited zircons from arc volcanic rocks to constrain the depositional age and sources of the PQU.

Geological Framework

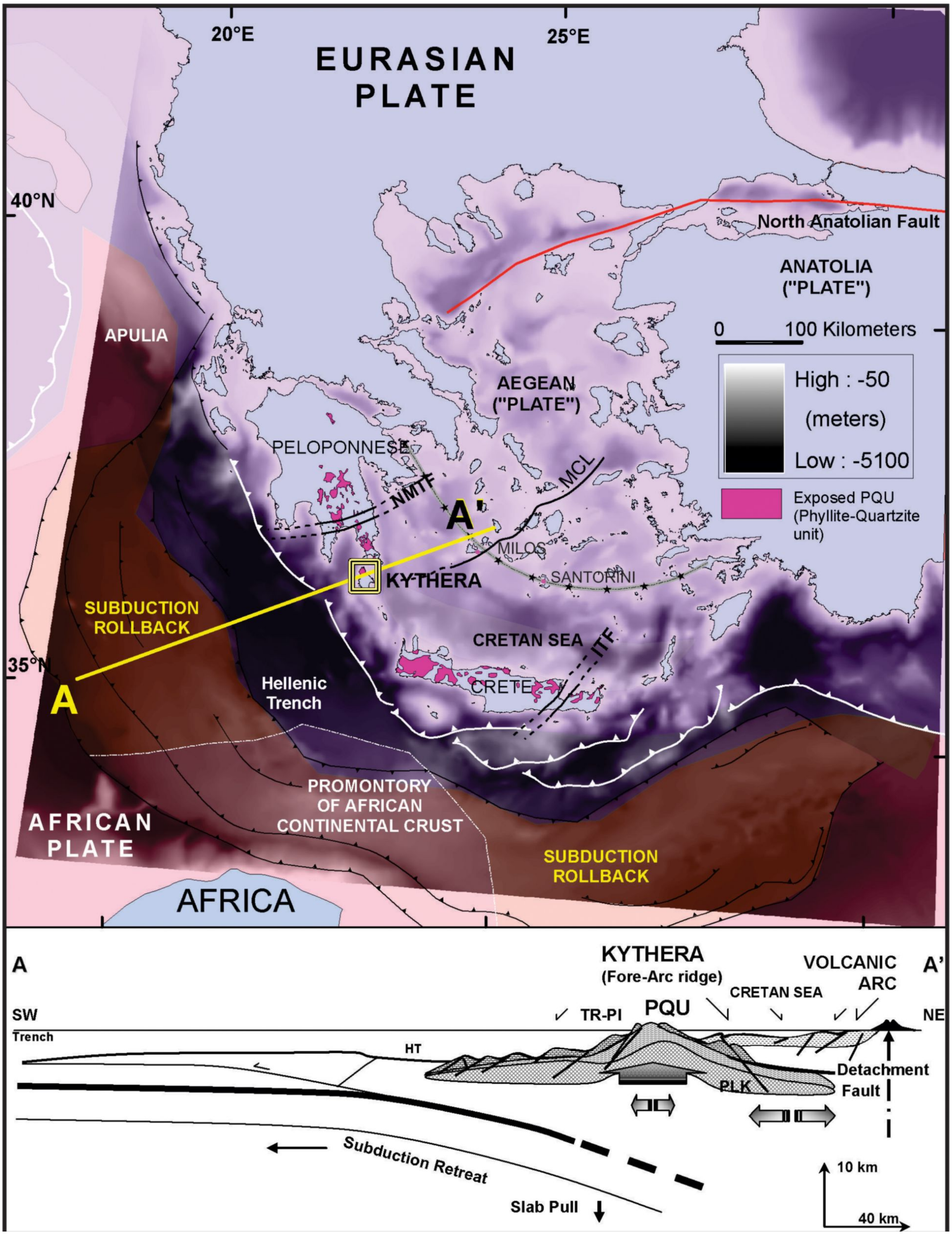
The Late Miocene-Recent extensional opening of the Cretan sea and associated exhumation of high pressure (HP) metamorphic rocks is the most recent major tectonic event that contributed to construction of the Peloponnese-Cretan ridge. Extension was accompanied by Late Pliocene to Recent volcanism along the Hellenic volcanic arc in the Sousaki, Methana, Milos, Santorini, Nisyros, and Kos areas. In addition, Late Miocene granitoids intruded the exhumed Middle-Late Miocene HP-rocks in the South Aegean.

The protolith of the metamorphic Phyllite-Quartzite unit (PQU) is interpreted to be a mid-Carboniferous to Triassic rift sequence (Krahl *et al.* 1983) that formed during opening of a southern branch of the Neotethyan ocean (Pe-Piper 1982, Seidel *et al.*, 1982; Robertson and Dixon, 1984). However, a granitic orthogneiss emplaced within the PQU at 323 ±3 Ma (U-Pb on zircon; Seidel *et al.*, 2006; Xypolias *et al.*, 2006) raises a question about the interpreted age of the rift sequence. The protolith and depositional age of the PQU in the Hellenic forearc ridge and within HP-rocks exposed in the Cyclades, including on Milos and Santorini Islands, as well as exposures in Attiki remain un-constrained. The HP-LT metamorphic sequences of the Phyllite-Quartzite unit (PQU) on Crete are likely Late Palaeozoic based on Tethyan deep water fossils (Krahl *et al.*, 1983; 1986).

There are very few published U/Pb ages from detrital or inherited zircons from the metamorphic basement of the entire Hellenic forearc and volcanic arc. Zircons from a Carboniferous orthogneiss that is intercalated with the metasedimentary rocks in the PQU from Kythera give Late Archaen-Early Proterozoic ages suggesting derivation from ancient crust in the basement of the External Hellenides (Xypolias *et al.*, 2006). Pan-African, Variscan, and younger zircon ages have been reported from orthogneisses from the Chamezi and Myrsini crystalline complexes in Eastern Crete (Romano *et al.*, 2004). Late Archaean-Early Proterozoic U-Pb ages have been reported for detrital zircons from metasediments from central Crete (Galinos beds; Kock *et al.*, 2007), the Menderes massif (Kroner & Sengor, 1990) and the Cycladic crystalline massif (Keay & Lister, 2002).

Along the entire Cretan-Peloponnese ridge metamorphic rocks including gneisses or blueschist rocks frequently occur as lenses within the phyllites. These may be part of the PQU unit or an exotic unit tectonically intercalated in the PQU. Lenses of metamorphic rocks in the PQU rocks share a similar Cenozoic tectonothermal history (e.g., Marsellos *et al.*, 2010), but it is unclear if they were together prior to Cenozoic time due to the lack of sufficient U-Pb zircon data.

Figure 1. Tectonic setting of the South Aegean arc.

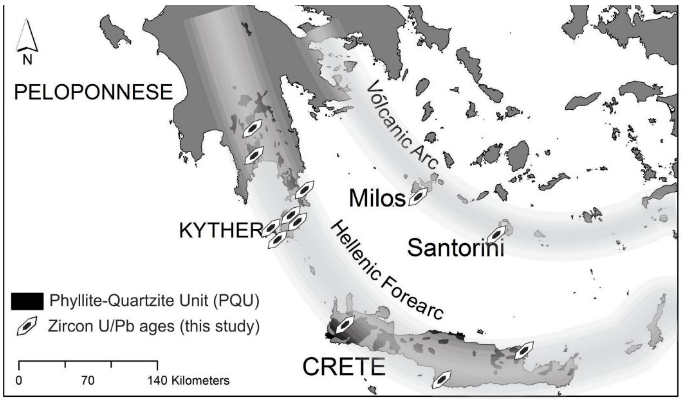


Bathymetry shown by a semi-transparent DEM layer; a cross section line A - A' along a NE-SW line through the Kythera strait.

Methods

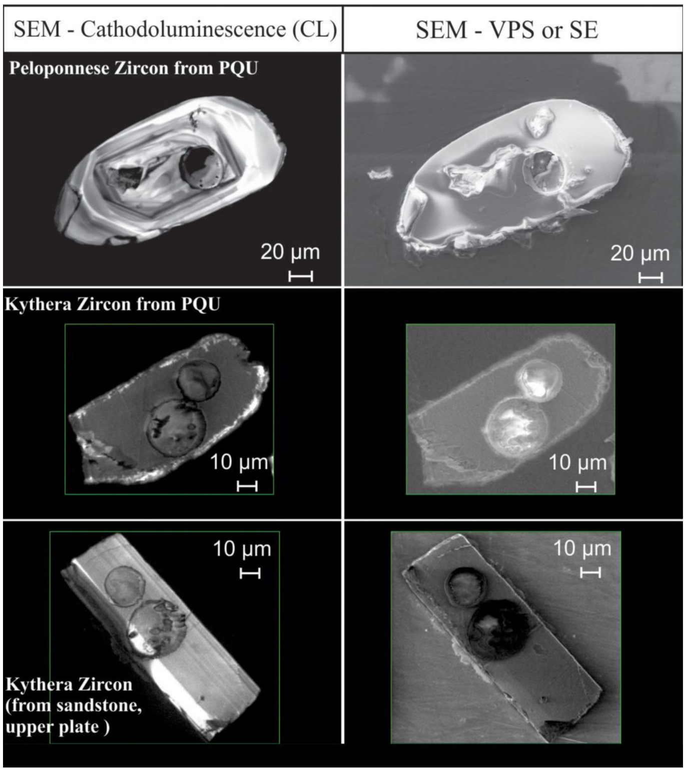
Samples were collected from PQU rocks from the Hellenic forearc ridge in South Aegean and from within the present volcanic arc (Fig. 2). The samples were crushed with a hydraulic press and a rotary mill. Zircon separation was carried out using hydro-gravimetric (Wilfley table), magnetic (Frantz isodynamic separator) and density (tetra-bromo-ethylene and methylene iodide) separation techniques followed by handpicking under a binocular microscope. Zircon grains were mounted in Teflon, sectioned and polished. Zircon grains were imaged on a SEM fitted with cathodoluminescence (CL) detector to characterize chemical zoning, and to identify core-rims relationships (Hunchar and Miller, 1993; Nasdala *et al.*, 2003). SEM imaging was performed using Variable Pressure (VPS) or Secondary Electrons (SE) with no coating on the samples (Fig. 3). Zircons vary from *ca.* 80 to 280 μm length, and their morphology ranges from long prismatic to isometric. Most of the detrital zircons show some rounding.

Figure 2. Distribution of zircon U/Pb samples in the Phyllite-Quartzite Unit of Peloponnese, Kythera, Crete, Santorini, and in the Cyclades blueschist of Milos.



Sample localities are shown in the index map. The black areas in the index map indicate the exposures of the PQU.

Figure 3. Cathodoluminesence (CL), variable pressure (VPS) images of zircon from selected Aegean samples.

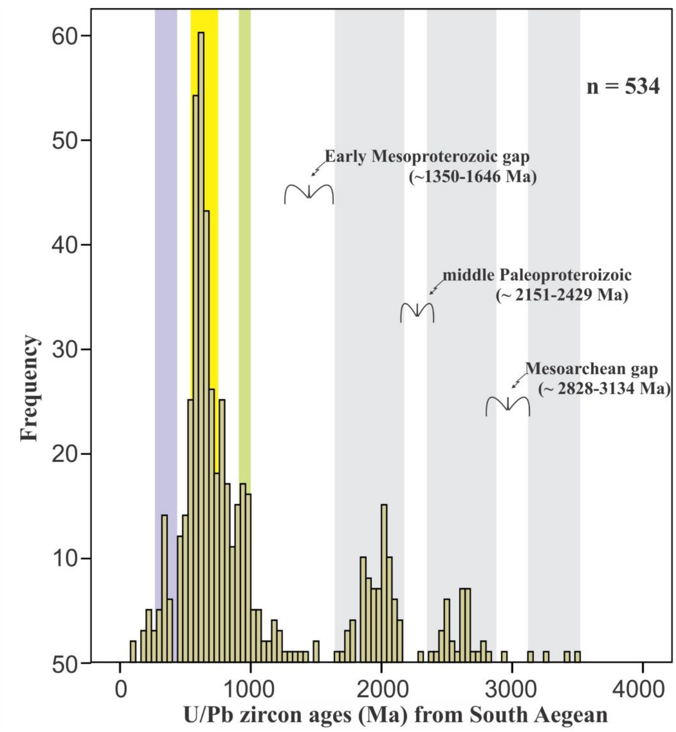


Zircons were mounted in teflon and polished to expose approximate midsections. White circles identify position and true size of MC-LA-ICPMS analytical spots. The smaller spot is from the U-Pb analyses. Scale is indicated by white bar.

Laser ablation U-Pb analyses were performed at the University of Florida and at the Arizona LaserChron Center. Analyses at the University of Florida were performed using a Nu-Plasma multi-collector inductively-coupled plasma mass spectrometer (MC-ICP-MS) following methods described by Mueller *et al.* (2008). A New Wave 213 nm laser was used for the laser ablation experiments. The U-Pb isotope analyses were performed on spots with 30 microns beam size, 6Hz, and 60% power. Isotopic data were acquired during the analyses using Time Resolved Analysis (TRA) software provided by Nu-Instruments. Before the ablation of each zircon a 20s on-peak zero was determined on the blank He and Ar gases with closed laser shutter. Following blank acquisitions individual zircons underwent spot analyses for 30s. Every 10 analyses of unknown zircons were “bracketed” by 2 analyses of FC-1 (Forest Center, Minnesota) zircon standard. Raw isotopic data obtained from the LA-MC-ICP-MS analyses were reduced with in-house Microsoft

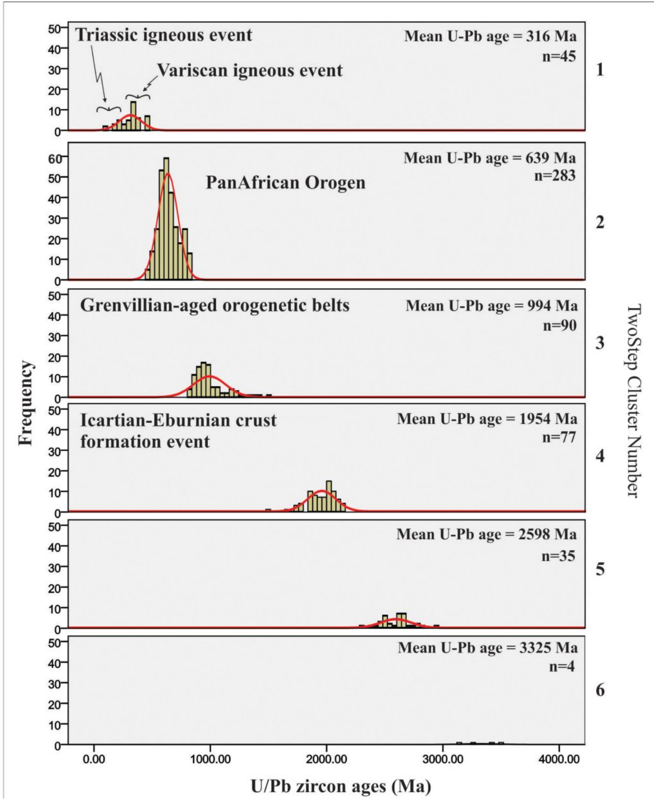
Excel© spreadsheet. Representative age errors based on the long-term reproducibility of FC-1 standard were 2% for ^{206}Pb=^{238}U (2σ) and 1% for ^{207}Pb=^{206}Pb (2σ) for more details see Mueller *et al.* (2008). A small subset of the U-Pb analyses were performed at the Arizona Laser-Chron Center using a New Wave/Lambda Physik DUV193 Excimer laser (operating at a wavelength of 193 nm) using a spot diameter of 30 mm. The ablated material was carried in helium into the plasma source of a GVI Isoprobe equipped with a flight tube of sufficient width that U, Th, and Pb isotopes were measured simultaneously. Each analysis consisted of one 20-s integration on peaks with the laser off (for backgrounds), 20 1-s integrations with the laser firing, and a 30-s delay to purge the previous sample and prepare for the next analysis. ^{206}Pb/^{238}U ages are quoted for analyses younger than 1.0 Ga, whereas ^{207}Pb/^{206}Pb ages are quoted for analyses older than 1.0 Ga. Only zircon U-Pb analyses for grains less than 10% discordant were plotted in a histogram (Fig. 4) and they were classified into groups (Fig. 5) and decomposed for the peak age analysis (Fig. 6) after using Isoplot (Ludwig, 2003) and SPSS, 2Step-cluster analysis.

Figure 4. U/Pb zircons ages from South Aegean.



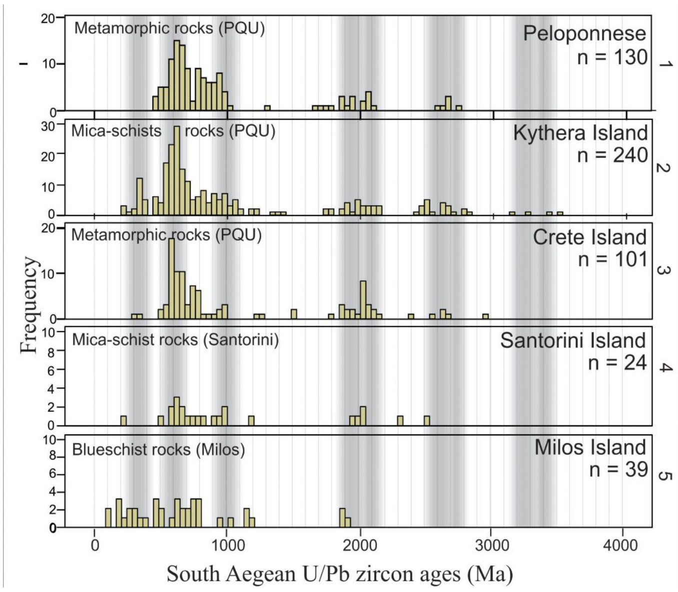
^{206}Pb/^{238}U ages are quoted for analyses younger than 1.0 Ga, whereas ^{207}Pb/^{206}Pb ages are quoted for analyses older than 1.0 Ga. Grey shaded bars are important thermal events (discussion in the text).

Figure 5. Decomposed zircon U/Pb age populations from South Aegean using 2Step-cluster analysis.



^{206}Pb/^{238}U ages are quoted for analyses younger than 1.0 Ga, whereas ^{207}Pb/^{206}Pb ages are quoted for analyses older than 1.0 Ga.

Figure 6. U-Pb ages of zircons from localities of the forearc and volcanic arc at the South Aegean.



^{206}Pb/^{238}U ages are quoted for analyses younger than 1.0 Ga, whereas ^{207}Pb/^{206}Pb ages are quoted for analyses older than 1.0 Ga. Grey shaded bars are important thermal events (discussion in the text).

Results

U/Pb analyses of 595 zircons from 10 samples yielded more than 500 pre-Carboniferous ages (Table 1 - See Appendix A.). The samples included metasediments from the Hellenic forearc in Kythera, Peloponnese and Crete, and from the Hellenic volcanic arc from Milos, and Santorini (Fig. 2). Pre-Carboniferous ages (n=502) were derived from all the detrital zircons in metasediments from the forearc and volcanic arc. Post-Carboniferous U-Pb ages (n=33) were less abundant, and completely absent from the Peloponnese detrital samples. Blueschist facies rocks from Milos yielded Carboniferous and Late Cretaceous zircons and along with some inherited cores of pre-Carboniferous events.

A total of 534 zircon grains out of the 595 grains are less than 10 percent discordant. These concordant zircons show a wide range of ages that when pooled reveal populations at *ca.* 60-80 Ma, 180-220 Ma, 300-360 Ma, 500-570 Ma, 600-680 Ma, 900-1100 Ma, ~ 2 Ga, 2.5 Ga, and 3.3 Ga (Fig. 4). A summary of major zircon age populations along with major Phanerozoic and Precambrian events is graphically displayed in Figure 5. The main populations are all defined by more than 35 individual analysis; ages younger than 650 Ma compose almost half (n=218) of the total number of analyses. The most prominent peaks from the combined analyses are also the youngest due probably to the better preservation potential of younger zircons with less radiation damage. Populations correspond to the Cyclades high grade metamorphism ~ 80-60 Ma, the Triassic igneous event (220-180 Ma; Finger *et al.*, 2002; Romano *et al.*, 2004), the Variscan igneous event (350-320 Ma; Keay *et al.*, 2001; Keay & Lister, 2002; Xypolias, 2006), the PanAfrican Orogen (640-540 Ma; e.g. Nance and Murphy, 1994) the Grenvillian-aged orogenetic belts (1.1-0.9 Ga; e.g. Dalziel, 1997; Kemp *et al.*, 2006; Mueller *et al.* 2008), the Icartian-Eburnian crust formation event that is known from the West African Craton (~ 2 Ga; e.g., Ennih and Liegeois, 2001; Egal *et al.*, 2002; Walsh *et al.*, 2002). There is smaller population of early Paleoproterozoic and Neo-Archean zircon centered at about 2.5 Ga. The four oldest zircons give concordant Paleoarchean ages of 3134 ±9.4 Ma, 3264 ±9.4 Ma, 3416 ±9.4 Ma, 3487 ±9.5 Ma and are all from a metasedimentary unit sampled from the upper plate of the detachment fault in Kythera.

There are three distinctive gaps in the zircon age populations that occur between the main peaks: these include no grains with early Mesoproterozoic (~1350-1646 Ma), middle Paleoproteroizoic (~ 2151-2429 Ma), and Meso-archean (~ 2828-3134 Ma) U-Pb ages.

Discussion

The most salient characteristic of the detrital zircon U-Pb data is the preponderance of ages between 500-650 Ma in all samples from the forearc exposures in Peloponnese, Kythera, and western Crete, and the volcanic arc in Santorini and Milos (Fig. 6, 7). This general characteristic suggests that the original provenance of Hellenic forearc Aegean detrital zircons is Pan-African. The youngest detrital zircon grains provide an estimate of the maximum age of deposition of the PQU protolith. Taken in aggregate, the range of minimum ages and major peak ages of the Hellenic detrital zircon grains from Peloponnese, Kythera, Crete, and Santorini HP-LT rocks suggests that they share a common age of deposition. Milos and Santorini islands are located in the Recent volcanic arc and share the same basement. Blueschist facies rocks from Milos yield additional post-Variscan detrital zircon grains, while maintaining the older zircon age populations and similar Late Miocene zircon fission-track ages with the PQU samples from the forearc (Marsellos *et al.*, in review). It is, therefore, possible that the Milos bluschist rocks are not metamorphosed PQU, even though they share the same tectonothermal history. An exotic rock unit could have been structurally emplaced within the PQU during the Late Miocene Hellenic subduction. Overall, the detrital and inherited zircon U/Pb ages from all of the South Aegean metamorphic basement samples are similar suggesting that all of the rocks correlated with the PQU originated from the same sources and deposited at about the same time.

Fault-bounded lenses of Potamos gneiss (Petrocheilos, 1966) occur within schists of the PQU on Kythera and locally along the entire Cretan-Peloponnese ridge. U-Pb zircon age population from the Potamos gneiss (Xypolias *et al.*, 2006) are similar to those from the PQU with the exception of the additional Variscan-aged and Late Cretaceous zircons. The presence of the younger zircons suggest that the gneisses have a different provenance and younger maximum depositional age than the PQU. This suggests that the Potamos gneisses are an exotic unit that was structurally emplaced within the PQU after Cretaceous time. These results, however, do not reveal if the gneisses were emplaced into the PQU basement during the Variscan, integrated during Hellenic subduction (Late Eocene-Early Miocene) or during exhumation of the Hellenic HP-LT rocks (Middle Miocene-Late Miocene).

Mica-schist of the PQU show arc-parallel extensional fabric and zircon fission track cooling ages of 10-13 Ma related to exhumation during expansion of the arc during subduction roll-back (Marsellos & Kidd, 2008). The Potamos gneisses show mostly arc-normal extensional structures and younger zircon fission-track cooling ages (ca. 9 Ma) (Marsellos *et al.*, 2010). This suggests that the tectonic juxtaposition of the Potamos gneiss and PQU took place during the exhumation after mica-schists experienced the localized arc-parallel extension (Marsellos & Kidd, 2008). The allochonous nature of the gneiss and younger cooling ages suggests that tectonic emplacement occurred within about a million years of arc expansion (Marsellos *et al.*, 2010).

The detrital zircon age populations from the PQU and intercalated Variscan units constrain the origins of the basement and Series rocks of the South Aegean forearc and volcanic arc. Four Precambrian crustal development cycles at 2700-2500, 2200-1900, 1200-900, and 800-550 Ma were highlighted by Gebauer (1993) as characteristic of the European Variscides. The periods of crustal development suggests derivation of the Variscanides from West Gondwana (Gebauer, 1993). Zircon age populations of the metamorphic rocks of the South Aegean, as well as detrital age populations in Central and North Aegean units (Keay & Lister, 2002; Meinhold *et al.*, 2008) are similar to the Variscan tectonic cycles. The Aegean fore arc, arc and back arc detrital zircons (this study and Keay & Lister, 2002) lack Mesoproterozoic zircons, which would be expected from Laurasian (Williams and Claesson, 1987) and East Gondwana sources. The abundance of 550-650 Ma zircons along with populations consistent with the Variscan, and lack of Mesproterozoic zircons, suggests sources from North and West Africa, Arabia, and the Menderes Massif of western Turkey (Kroner and Sengor, 1990; Cahen *et al.*, 1984; Reischmann *et al.*, 1991; Ring *et al.*, 1999; Keay & Lister, 2002).

The four Paleoarchean zircons are from the upper plate sandstone on Kythera, which did not experience the Miocene thermal event in the lower plate (Marsellos *et al.*, 2010b). Paleoarchean zircons are absent in the Miocene metasedimentary rocks from Crete, Kythera, Peloponnese, Milos and Santorini, possibly because the metamorphism recrystallized or broke down any ancient zircons with substantial radiation damage. The presence of these ancient zircons may also provide constraints to the origin of the pre-Alpine basement. It is most likely that the Paleoarchean zircons were derived from the Kalahari craton in South Africa (e.g., Kranendonk *et al.*, 2009) or another Gondwanan Archean craton (e.g., Pilbara or Yilgarn of Western Australia, Smithies *et al.*, 1999; Smithies *et al.*, 2001; Bagas *et al.*, 2008), either as first or polycyclic detritus.

Of the current hypotheses for the origin of the pre-Alpine basement of the External Hellenides – derived by rifting of Apulia from the northern margin of Gondwana (Robertson *et al.*, 1991, 1996), the western termination of the Cimmerian super-terrane (Stampfli & Mosar, 1999; Stampfli & Borel, 2002), and Permo-Triassic rifting of Cimmerian fragments coeval with southward subduction of the Palaeotethyan ocean beneath northern Gonwana (Sengor *et al.*, 1984) – the Permo-Triassic rift model of Sengor *et al.* (1984) is most consistent with southern Gondwanan sources.

Conclusions

Zircons derived from metasedimentary of the South Aegean micro-plate show a U-Pb crystallization ages ranging from Recent to Paleoarchean. Mean U-Pb ages ($^{206}Pb/^{238}U$ or $^{207}Pb/^{206}Pb$) of distinct populations of zircons are about 316, 639, 994, 1954, 2598 and 3325 Ma. These populations are consistent with parts of the detritus that now makes up the South Aegean basement having a source within orogenic belts of North African and Gondwana. There are three distinctive age gaps evident in the Aegean detrital zircon age populations: early Mesoproterozoic (~1350-1646 Ma), the late Paleoproterozoic (~2151-2429 Ma), and the Mesoarchean (~ 2828-3134 Ma). These detrital zircon age populations and gaps provide a reference for reconstructing the position of crustal material derived from different parts of Gondwana (the Pelagonian "terrane") that accreted against the active European continental margin.

References

Anderson, T., 2005, Detrital zircons as tracers of sedimentary provenance: limiting conditions from statistics and numerical simulation: Chemical Geology, v. 216 (3-4), p. 249-270. 10.1016/j.chemgeo.2004.11.013

Bagas, L., Bierlein, F.P., Bodorkos, S., Nelson, D.R., 2008. Tectonic setting, evolution and orogenic gold potential of the late Mesoarchaean Mosquito Creek Basin, North Pilbara Craton, Western Australia. Precambrian Research, vol. 160, 3-4, p. 227-244.

Bellucci, J., McDonough, W.F., Rudnick, R.L., 2011. Thermal history and origin of the Tanzanian Craton from Pb isotope thermochronology of feldspars from lower crustal xenoliths. Earth and Planetary Sci. Let., vol. 301, 3-4, p. 493-501.

Bowring, S.A. and Williams, I.S., 1999. Priscoan (4.00–4.03 Ga) orthogneisses from northwestern Canada, Contrib. Mineral. Petrol. 134, pp. 3–16.

Cahen, L., Snelling, N.J., Delhal, J., and Vail, J.R., 1984, The geochronology and evolution of Africa: Oxford, Clarendon Press, 512 p.

Dalziel, I.W.D., 1997. Neoproterozoic–Paleozoic geography and tectonics: review, hypothesis, environmental speculation. Geological Society of America Bulletin 109, 16–42.

Davis, W.J. and Bleeker, W., 1999. Timing of plutonism, deformation, and metamorphism in the Yellowknife Domain SlaveProvince, Canada, Can. J. Earth Sci. 36 (1999), pp. 1169–1187.

Davis, D.W., Williams, I.S., and Krogh, T.E., 2003, Historical development of U-Pb geochronology, in Hanchar, J.M., and Hoskin, P.W.O., eds., Zircon: Reviews in Mineralogy and Geochemistry, v. 53, p. 145-181.

Egal, E., Thiéblemont, D., Lahondére, D., Guerrot, C., Costea, C.A., Iliescu, D., Delor, C., Goujou, J.C., Lafon, J.M., Tegyey, M., Diaby, S., Kolié, P., 2002. Late Eburnean granitization and tectonics along the western and northwestern margin of the Archean Kénéma-Man domain (Guinea, West African Craton). Precambrian Research 117, 57–84

Ennih, N., Liégeois, J.P., 2001. The Moroccan Anti-Atlas: the West African craton passive margin limited Pan-African activity. Implications for the Northern limit of the craton. Precambrian Research 112, 289–302.

Fedo, C.M., Sircombe, K., Rainbird, R., 2003, Detrital zircon analysis of the sedimentary record, in Hanchar, J.M., and Hoskin, P.W.O., eds., Zircon: Reviews in Mineralogy and Geochemistry, v. 53, p. 277-303.

Finger, F., Krenn, E., Riegler, G., Romano, S. & Zulauf, G. 2002. Resolving Cambrian, Carboniferous, Permian and Alpine monazite generations in the polymetamorphic basement of eastern Crete (Greece) by means of the electron microprobe. Terra Nova, 14, 233–240.

Gebauer, D., 1993. The Pre-Alpine evolution of the continental crust of the Central Alps—An overview, in Raumer, J.F.v., and Neubauer, F., eds., Pre-Mesozoic geology in the Alps: Berlin, Springer-Verlag, p. 93–117.

Gehrels, G.E., 2010, Detrital zircon U-Pb geochronology: Current methods and new opportunities, in Busby, C.J., and Azor, A., eds., Recent advances in tectonics of sedimentary basins: Hoboken, New Jersey, Blackwell Publishing (in press).

Hanchar, J.M., and C. F.Miller, 1993. Zircon zonation patterns as revealed by cathodoluminesence and backscattered electron images: Implication for interpretation of complex crustal histories, Chem. Geol., 110, 1–13.

Keay, S., Lister, G. & Buick, I. 2001. The timing of partial melting, Barrovian metamorphism and granodiorite intrusion in the Naxos metamorphic core complex, Cyclades, Aegean Sea, Greece. Tectonophysics, 342, 275–312.

Keay, S. & Lister, G. 2002. African provenance for the metasediments and metaigneous rocks of the Cyclades, Aegean Sea, Greece. Geology, 30, 235–238.

Kemp, A.I.S., Hawkesworth, C.J., Paterson, B.A., Kinny, P.D., 2006. Episodic growth of the Gondwana supercontinent from hafnium and oxygen isotopes in zircon. Nature 439, 580–583.

Kock, S., Martini, R., Reischmann, T., Stampfli, G.M., 2007. Detrital zircon and micropalaeontological ages as new constraints for the lowermost tectonic unit (Talea Ori unit) of Crete, Greece

Kolodner, K., Avigad, D., McWilliams, M.,Wooden, J.L.,Weissbrod, T., Feinstein, S., 2006. Provenance of north Gondwana Cambrian–Ordovician sandstone: U–Pb SHRIMP dating of detrital zircons fromIsrael and Jordan. GeologicalMagazine 143, 367–391.

Kosler, J., and Sylvester, P.J., 2003, Present trends and the future of zircon in U-Pb geochronology: laser ablation ICPMS, in Hanchar, J.M., and Hoskin, P.W.O., eds., Zircon: Reviews in Mineralogy and Geochemistry, v. 53, p. 243-275.

Krahl, J., Kaufmann, G., Kozur, H., Richter, D., Forster, O. & Heinritzi, F., 1983. Neue Daten zur Biostratigraphie und zur tektonischen Lagerung der Phyllit-Gruppe und der Trypali-Gruppe auf der Insel Kreta (Griechenland). Geol. Rdsch., 72, p. 1147-1166.10.1007/BF01848358

Krahl, J., Kaufmann, G., Richter, D., Kozur, H., Moller, I., Forster, O., Heinritzi, F. & Dornsiepen, U., 1986. Neue Fossilfunde in der Phyllit-Gruppe Ost-Kretas (Griechenland). - Z. Dtzch. geol. Ges., 137, p. 523-536.

Kranendonk, M.J. Van, Kroner, A., Hegner, E., Connelly, J., 2009. Age, lithology and structural evolution of the c. 3.53 Ga Theespruit Formation in the Tjakastad area, southwestern Barberton Greenstone Belt, South Africa, with implications for Archaen tectonics. Chemical Geology, 261, p. 115-139.10.1016/j.chemgeo.2008.11.006

Kroner, A. & Sengor, A.M.C. 1990. Archean and Proterozoic ancestry in late Precambrian to early Paleozoic crustal elements of southern Turkey as revealed by single-zircon dating. Geology, 18, 1186–1190.

Ludwig, K.R., 2003, User's Manual for Isoplot/Ex, Version 3.0, A geochronological toolkit for Microsoft Excel Berkeley Geochronology Center Special Publication, v. 4, Berkeley Geochronology Center, 2455 Ridge Road, Berkeley, CA 94709, USA.

Marsellos, A.E & Kidd, W.S.F., 2008. Extension and Exhumation of the Hellenic Forearc Ridge in Kythera. J.Geology, vol. 116, p.640-651.10.1086/591995

Marsellos, A.E., Kidd, W.S.F., Garver, J.I., 2010. Extension and exhumation of the HP/LT rocks in the Hellenic forearc ridge. American Journal of Science, vol. 310, p. 1-36.10.2475/01.2010.01

Marsellos, A.E., Kidd, W.S.F., Garver, J.I., Kyriakopoulos, K.G., 2010b. Exhumation of the Hellenic accretionary prism – evidence from fission-track thermochronology. Hellenic Geological Society of Greece, vol. XLIII, No.1, p. 309-319.

Manya, S., Kobayashi, K., Maboko, M.A.H., and Nakamura, E., 2006. Ion microprobe zircon U–Pb dating of the late Archean metavolcanics and associated granodiorites of the Musoma–Mara Greenstone Belt, Northeast Tanzania: implications for the geological evolution of the Tanzania Craton, J. Afr. Earth Sci., 45:3, p. 355–366

Mueller, P.A., Kamenov, G.D., Heatherington, A.L., and Richards, J., 2008. Crustal evolution in the Southern Appalachian Orogen: evidence from Hf isotopes in detrital zircons. Journal of Geology, 116, 414-422.10.1086/589311

Nance, R.D., and Murphy, J.B., 1994, Contrasting basement isotopic signatures and the palinspastic restoration of peripheral orogens: Example from the Neoproterozoic Avalonian-Cadomian belt: Geology, v. 22, p. 617–620.

Nasdala, L., M. Zhang, U. Kempe, G. Panczer, M. Gaft, M. Andrut, and M. Plotze 2003. Spectroscopic methods applied to zircon, in Zircon, Rev. Mineral. Geochem., vol. 53, edited by J. Hanchar and P. Hoskin, pp. 427– 467, Mineral. Soc. of Am., Washington, D. C.

Pe-Piper, G., 1982. Geochemistry, tectonic setting and metamorphism of mid-Triassic volcanic rocks of Greece. Tectonophys. 85:253-272.10.1016/0040-1951(82)90105-6

Reischmann, T., Kroner, A., Todt, W., Durr, S., and Sengor, A.M.C., 1991. Episodes of crustal growth in the Menderes Massif, W. Turkey, inferred from zircon dating: Terra Abstracts, v. 3, p. 34.

Robertson, A.H.F. & Dixon, J.E., 1984. Introduction: aspects of the geological evolution of the Eastern Mediterranean. In Dixon, J.E. & Robertson, A.H.F. (eds) The Geological Evolution of the Eastern Mediterranean. Geol. Soc. Lond. Spec. Pub. 17:1-74.

Romano, S.S., Dorr, W. & Zulauf, G. 2004. Cambrian granitoids in the pre-Alpine basement of Crete (Greece): evidence from U–Pb dating of zircon. International Journal of Earth Science, 93, 844–859.

Seidel, E., Kreuzer, H. & Harre, W., 1982. A Late Oligocene/ Early Miocene High Pressure Belt in the External Hellenides. Geol. Jahrb. E23:165-206.

Sengor, A.M.C., Yılmaz, Y. & Sungurlu, O. 1984. Tectonics of the Mediterranean Cimmerides: nature and evolution of the western termination of Palaeo-Tethys. In: Dixon, J.E. & Robertson, A.H.F. (eds) The Geological Evolution of the Eastern Mediterranean. Geological Society, London, Special Publications, 17, 77–112.

Smithies, R.H., 1999. Yule, W.A. Sheet 2556: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes.

Smithies, R.H., Nelson, D.R., Pike, G., 2001. Development of the Archaean Mallina Basin, Pilbara Craton, northwestern Australia; a study of detrital and inherited zircon ages. Sedimentary Geology, vol. 141-142, p. 79-94.10.1016/ S0037-0738(01)00069-0

Stampfli, G.M. & Borel, G.D. 2002. A plate tectonic model for the Palaeozoic and Mesozoic constrained by dynamic plate boundaries and restored synthetic oceanic isochrones. Earth and Planetary Science Letters, 169, p. 17–33.

Stampfli, G.M. & Mosar, J. 1999. The making and becoming of Apulia. Memorie di Scienze Geologiche, 51, p. 141–154.

Teixera, W., Tassinari, C.C.G., Cordani, U.G., and Kawashita, K., 1989, A review of the geochronology of the Amazonian craton: Tectonic implications: Precambrian Research, v. 42, p. 213–227.

Thomson, S.N., Stockhert, B., Brix, M.R., 1998. Thermochronology of the high-pressure metamorphic rocks of Crete, Greece: implications for the speed of tectonic processes. Geology 26, vol. 259-262.

Walsh, G.J., Aleinikoff, J.N., Benziane, F., Yazidi, A., Armstrong, T.R., 2002. U–Pb zircon geochronology of the Paleoproterozoic Tagragra de Tata inlier and its Neoproter-ozoic cover, western Anti-Atlas, Morocco. Precambrian Research 117, 1–20.

Williams, I.S., and Claesson, S., 1987, Isotopic evidence for the Precambrian provenance and Caledonian metamorphism of high grade paragneisses from the Seve Nappes, Scandanavian Caledonides: Contributions to Mineralogy and Petrology, v. 97, p. 205–217.

Wirth, K.R., Vervoot, J.D., Weisberger, B., 2004. Origin and evolution of the Kilimafedha greenstone belt, eastern Tanzania Craton: evidence from Pb isotopes. Geological Society of America Abstracts with Programs 36, 244.

Xypolias, P., Dorr, W., Zulauf, G., 2006. Late Carboniferrous plutonism within the pre-Alpine basement of the External Hellenides (Kithira, Greece): evidence from U-Pb zircon dating. Journal of Geological Society, London, Vol. 163, pp. 539-547.10.1144/0016-764904-114

A. Table 1

Table 1 "Geochronologic results of zircons from localities of the forearc and volcanic arc at the South Aegean" is available for download from *http://virtualexplorer.com.au/article/2011/284/detrital-zircon-u-pb-and-hf-isotopic-data/media/Table-1_AegeanZircons.pdf*