PERGAMON

Quaternary Science Reviews 22 (2003) 2363–2367

QSR

Correspondence

Comment on: "The age of Late Pleistocene shorelines and tectonic activity of Taranto area, southern Italy" by G. Bellouomini, M. Caldara, C. Casini, M. Cerasoli, L. Manfra, G. Mastrronuzzi, G. Palmentola, P. Sanso, P. Tuccimei, and P.L. Vesica [Quaternary Science Reviews, 21, 525–547] ☆

P.J. Hearty[a,*], G. Dai Pra[b]

[a] *School of Earth Sciences, James Cook University, Townsville 4811, QLD, Australia*
[b] *Via Trionfale, 13840 ñ 00135 Rome, Italy*

Received 5 July 2002; accepted 24 April 2003

1. Introduction

We wish to address our concerns regarding the paper by Belluomini et al. (2002) recently published in Quaternary Science Reviews (21 (2002) 525–547). There are many flaws and inconsistencies in both their field and laboratory work that seriously impair this study. In particular, the authors have not established a stratigraphic framework in which to evaluate geochronological data. The stratigraphic names do not correspond with petrography, stratigraphy, geomorphology, biostratigraphy, or apparent age. Correlations are made on the basis of amino acid racemization (AAR) data despite consistent disagreement with other stratigraphic and geochronological evidence. D/L ratios are selectively retained and rejected, but not in accordance with the author's protocol. Despite numerous warnings regarding the hazards using mollusks for U-series dating, ages from 44 to 116.8 ka are published. Comparisons with important and relevant data from nearby sites are not made. Hearty and Dai Pra's (1992) and related studies are challenged, yet none of our data have been confronted in the Belluomini et al. (2002) study.

Among their conclusions, the authors have determined that: (1) *Strombus* was present continuously for the period between OIS 5e and 5c from 140 to 90 ka; (2) a sea-level highstand persisted for over 50 ka during this period; (3) an OIS 3 transgression at ~48 ka left marine deposits above present sea level; and (4) there is support for "the reliability of U-series ages obtained for mollusks". We point out in this comment why we disagree with these findings.

Their aims (p. 527 and following) are to provide: (1) "a reliable geomorphological and stratigraphic description of the Tyrrhenian deposits"; (2) "a new chronology based on AAR and U-series dating"; and (3) "an estimation of tectonic uplift rates". For the reasons outlined below, it is our opinion that minimal sound data are offered, and the science of the region is not progressed.

2. On stratigraphic correlation

Despite the fact that 19 taxa were named in the legend of Fig. 3, there is no symbol for *Strombus bubonius* (Sb). The term Tyrrhenian (by Issel (1914), not Deperet (1918)) is synonymous with "Senegalese Fauna" (Bonifay and Mars, 1959) with Sb as its figurehead. To exclude Sb from the biostratigraphic correlation scheme is nothing less than a drastic oversight. In their Table 1 (p. 526), they construct an incomplete list of sites and elevations containing Sb. Eight additional Sb localities are described in Hearty and Dai Pra (1992), and many more sites with Sb are recognized from Lizzano, Torre Castiglione, Vibo Valentia, C. Janni, and Ravagnese and Bovetto in Calabria.

It is unclear from this paper if any lithostratigraphic correlations have been established between outcrop sections. Do the alphabetical names in the legend in Fig. 3 represent petrological composition (A–H), sedimentary structures (L–N), discrete stratigraphic

☆ doi of article: 10.1016/S0277-3791(03)00149-5

*Corresponding author. Tel.: +61-07-4781-5283; fax: +61-07-4725-1501.

E-mail address: paul.hearty@jcu.edu.au (P.J. Hearty).

doi:10.1016/S0277-3791(03)00149-5

units, or none of the above? Are they a scheme for counting units or facies from the base (A) to the top (F, G, H, etc.) of the sections as they appear in the columnar sections in Fig. 3? There are additional cases where the lithologic symbol is equal, but the letters differ. And finally, in Fig. 5, lithology and age are equated under the number "4".

3. On rejection of D/L ratios

Justifications to exclude analyzed D/L ratios include:

(1) Samples whose "variations among shells of >10% were taken to represent age mixtures or unreliable values because of not detectable levels of amino acids. Such samples were rejected and additional shells analyzed" (p. 535).
(2) "Moreover, some samples have D/L ratios which are lower than those of mollusks from the same levels…" (p. 535).
(3) "…or which appear inconsistent with the stratigraphic data, and therefore they must be considered as reworked or rejuvenated samples." (p. 535).
(4) Roof (1997) pointed out that "coeval shells…may give different D/L values if individual shells have experienced different burial conditions and degrees of leaching. Based on this possible source of error some analyzed shells were rejected, and the values are not discussed in the paper." (p. 536).

3.1. Regarding the exclusions

RE #1 ("variations among shells of >10%…"): D/L results from MP8 and SV18 have standard deviations >10% (11% and 15%), respectively, but were NOT excluded "because of not detectable levels of amino acids". Instead, these shell samples were considered to be reworked (open circle). Both of these "reworked" means fall into the Aminozone *E* values of Hearty and Dai Pra (1992).

RE #2 ("samples with lower D/L ratios…"): Sites PR, ISP2, and SV22 "have D/L ratios which are lower than those of mollusks from the same levels…". These "lower" ratios have NOT been "considered as reworked or rejuvenated samples", instead, the double-mean values are interpreted as separate highstands during OIS 3 and 5a. However, a D/L of $0.51\pm0.02(2)$ was rejected in SV22 as "reworked", while the *Arca* mean of $0.25\pm0.01(4)$ was retained. The nearby sites ISP4 and ISP5 (Fig. 3) on Apodonia Beach are described simultaneously as Site 5 on p. 530. While the D/L of 0.51 in SV22 was rejected as reworked, a $0.51\pm0.01(5)$ from ISP4 was retained. Shells from *within* clasts in a marine conglomerate in ISP4 (Table 2) produced a mean of $0.55\pm0.01(5)$. The 0.55 values were retained, despite the fact that, by definition, shells within clasts from a thin basal conglomerate are reworked. These deposits probably represent an older marine transgression (Hearty and Dai Pra, 1992).

RE #3: (samples "which appear inconsistent with the stratigraphic data"): In several cases, a single stratigraphic unit without unconformity, soils, evidence of erosion, or significant facies transition is interpreted to represent *multiple high stands of sea level*. When are the D/L ratios "inconsistent", and when are they polymodal? While an obvious lithologic correlation exists between some levels, such as in Unit A in sections SV2, SV16, and SV18 (p. 533), these units produce unlike D/L ratios, that are interpreted to represent distinct high stands of sea level (e.g., Unit A in SV2 = OIS 5c, while Unit A in SV16 = OIS 5e at 139.6 ka).

RE #4: (apparent "burial conditions and degrees of leaching"): *Glycymeris* and *Cerastoderma* mean ratios from MP8 and SV18 are noted as "shallow depth of burial: leaching suspected", but were NOT rejected and appear in Table 2. On the basis of their drawings and descriptions in Fig. 3, it appears that samples from a majority of sections were taken from shallow depth of burial; indeed, less than 0.5 m below unit contacts in obvious cases MP7, MP8, PR, ISP2, ISP5, and possibly SV22. Shallow depth of burial may also result in increased surface heating and higher D/L ratios (which may have contributed significantly to the their retained 0.51 or 0.55 means in Table 2).

A converted D/L of 0.36 from Masseria Natrella (Site 2, MP8) was rejected on the basis of apparent leaching (p. 536, first paragraph) even though it agrees explicitly with Hearty and Dai Pra's (1992) 0.37 ± 0.02 (25) OIS 5e mean from Mar Piccolo. A coral age of 89.8 ± 4.8 ka from Site 1 does not agree with our coral age from the same section of 125 ka (Hearty and Dai Pra, 1992). Can this discrepancy also be ascribed to leaching? More problems are evident in Table 2 where D/L means of $0.43\pm0.01(5)$ (*Cerastoderma*) and $0.36\pm0.01(6)$ (*Glycymeris*) from MP7 and ISP2, respectively, yield different interpreted ages than the identical (at 1σ) associated coral ages of 89.8 ± 4.8 and 86.4 ± 4.2 ka from the same units. These statistically identical coral ages are later correlated with different highstands of OIS 5c and 5a. Curiously, these ages are concordant with Dai Pra and Stearns' (1977) 87 ± 4 ka coral age from neighboring Il Fronte. As implied by the authors, perhaps their young ages "could also be related to a sampling problem" (first paragraph, p. 539). We conclude from our analysis of their data that the authors follow none of their own protocol for sample exclusion.

3.2. On retained D/L data

In their Fig. 5, stratigraphic correlation of Unit B (alphabet in their Fig. 3, and by dashed lines in Fig. 5) is made across sections PR, ISP2, and ISP4, yet U-series

ages vary between 83.8, 44.2, 86.4, and 116.8 ka. D/L ratios likewise vary considerably between 0.22, 0.34, 0.27, 0.31, 0.36, and 0.51 across the same sections. There are no unconformities in Unit B (Figs. 3 and 5), implying continuous marine submergence between 44 and 117 ka!

Same Fig. 5: a correlation (alphabet/dashed lines) of Unit A in sections SV2, SV16, and SV18 is made, yet D/L ratios from Unit A range from 0.43, to 0.55, to 0.33. The 0.33 mean was excluded on the basis of "suspected leaching" (Table 2); the 0.55 equates with a 139.6 ka U-series coral age; and the 0.43 was correlated with an age of 90 ka (Fig. 4) (all within the same lithologic unit). Unit B, from adjacent SV22 yields a mean of $0.51 \pm 0.02(2)$ that was rejected (although it correlates with SV16); a 0.33 *Cerastoderma/Glycymeris* conversion was retained, while an identical *Glycymeris* mean of 0.33 from SV18 was rejected. On the basis of this poor quality of data, we question the significance of this "new chronology based on AAR and U-series dating"?

4. On U-series dating of mollusks

Despite numerous published warnings against the use of mollusks for U-series dating (Kaufman et al., 1971; Szabo, 1979; McLaren and Rowe, 1996), the authors persist in publishing these data. At Il Fronte, Mar Piccolo, Hoang and Hearty (1989) used unreworked (in some cases articularted and in growth position) *Glycymeris* shells to test the U-series mollusk dating application. Five *Glycymeris* shells from one single stratigraphic horizon yielded U-series mollusk ages of 101, 33, 29, 74, and 19.4 ka!

In contrast, three U-series ages on *Cladocora caespitosa* from the same unit at Il Fronte yielded consistent ages of 121, 117, and 128 ka (Hearty et al., 1986). Other coral samples from Masseria Saracino, Santa Teresiola (their site MP7), and Torre San Vito (near their site SV2?) returned concordant coral ages of 134, 125, and 134 ka, respectively.

Belluomini et al. (2002) state that under "rigorous protocol" and "independent systematics" they must "confirm the validity of the closed system assumption" associated with mollusk data. Was this rigorous protocol exercised in Belluomini et al. (2002)? How would they explain the results of Hoang and Hearty (1989) from a site and marine deposit situated in the center of their study area?

5. On tectonic uplift

"It is necessary to consider the present height of marine deposits and the depth at which they were deposited and not the elevation of the supposed coastline" (p. 544). It is also necessary to know accurately, the age of the deposits. Gignoux (1913) defined the Tyrrhenian coastline at +35 m, as Dai Pra and Stearns (1977) determined later at a more precise +28 m. We calculated an uplift rate for Taranto of 0.20 m/ka.

Belluomini et al. (2002) performed "facies analyses" on Sites 1 and 2, from which a depositional (water) depth of 10–15 m was suggested. Searching the text, we found no section on, or discussion of "facies analyses", but even if so, we suggest that it is impossible to estimate a paleo-water depth of to an accuracy of 10–15 m by "facies analysis". All factors considered, they calculate an uplift rate of 0.21–0.27 mm/yr (or m/ka) from Site 1 (Sta. Teresiola) and Site 2 (Mass. Natrella). However, the age of Site 2 is unknown (p. 536, rejected data), while their coral age from Site 1 disagrees with ours by 35 ka.

6. On previous work

We take issue with their comments (p. 326): "U-series ages determined on *C. caespitosa* specimens from these deposits (i.e., "the marine terrace deposits outcropping in, the Taranto region, have yielded different results between >300 and 87 ka, as there is as yet no satisfactory scheme for these deposits." And again on p. 539, regarding four coral ages of 87, 106, 130, and 154 ka from Dai Pra and Stearns (1977) (not Hearty and Dai Pra, 1985 or 1992): "the authors of the present work (i.e., Belluomini et al., 2002) believe that it could also be related to a sampling problem."

We do not understand what is implied here, but for Stearns in 1965–1977, the U-series method was still young, and potential problems associated with coral or mollusk dating corals were not yet fully realized. Over the course of following years, valuable lessons related to coral sampling and particularly cleaning procedures on *C. caespitosa* were learned from the pioneering work of Stearns and Thurber (1965, 1967) and Dai Pra and Stearns (1977). Further aware of potential problems created by leaching and surface heating, we maintained a meticulous collection program, intensive mechanical and chemical shell cleaning procedure, and a diligent preparation protocol for all the samples. The consistency of AAR and U-series results across the Mediterranean reflects this effort. Furthermore, the scheme presented at Il Fronte at Mar Piccolo in Puglia by Hearty and Dai Pra (1992) was sufficiently coherent that the Subcommission on Neogene Stratigraphy, Chairperson Prof. B.M. Cita, proposed (Cita and Castradori, 1994) that our sections be considered as the global boundary stratotype section and point (GSSP) (see also Dai Pra, 1995).

In the Hearty and Dai Pra (1992) study, twenty-five (25) *Glycymeris* shells from the *Strombus* level at Punta

Penna and Il Fronte alone in Mar Piccolo yielded a mean of 0.373 ± 0.020. Hearty and Dai Pra (1985, 1992) analyzed 56 individual *Glycymeris* shells from Sb levels from Taranto and the Ionian coast of Puglia to yield a mean of 0.388 ± 0.030. In Puglia, our studies employed more analyses on *Glycymeris* from *one level* (Aminozone E) than all the Belluomini et al. (2002) results combined.

These Aminozone E averages are equated with several U-series ages on the branching coral *C. caespitosa* from the same localities and stratigraphic units (3 from Il Fronte). The Ionian Sea *Glycymeris* averages fit into a regional Mediterranean framework consisting of over 100 sites, hundreds more *Glycymeris* ratios, and several additional U-series coral ages. This regional "inventory" of Last Interglacial deposits (Hearty, 1986) found that the *Strombus* fauna occurred only within Aminozone E, which is tied by U-series coral ages to OIS 5e. The fact is, that nearly all occurrences of *Strombus* fauna reported in the Mediterranean NOT associated with OIS 5e, appear to be based on U-series mollusk chronologies (Bernat et al., 1978; Zazo et al., 1984; Hillaire-Marcel et al., 1986; Zazo, 1999) of dubious accuracy.

We originally suggested the occurrence of a late OIS 5 highstand on the basis of our data from Mar Piccolo. A "banal" fauna from a marine layer above an upper palaeosol at Il Fronte produced younger *Helix* and *Glycymeris* ratios. These ratios constitute Aminozone C, which we *conservatively* correlated with OIS 5c or 5a (Hearty and Dai Pra, 1985).

Their statement (p. 541) that "according to Hearty and Dai Pra (1992) the sea level stand during OIS 5e and 5c was at about the same position…" is incorrect. We made no reference to OIS 5c sea levels in 1992. Hearty and Dai Pra (1985, p. 167) stated: "The Il Fronte section provides a continuous record through the aminozone E (stage 5e) and again in aminozone C (stage 5c or 5a). *The two episodes are separated by an unconformity developed during a period of subaerial exposure*."

In south Italy, uplift rates increase toward Calabria where the Last Interglacial shoreline has been uplifted over 100 m (Dumas et al., 1988; Westaway, 1993), and decreases to zero at Gallipoli in agreement with a geodynamic model proposed by Doglioni, (1991, 1994, and personal communication to GDP).

On the basis of their findings, the authors state that their results are not "in agreement with previous aminostratigraphy studies" (i.e., Hearty and Dai Pra, 1992). Indeed they are not. We believe that our stratigraphic and chronostratigraphic correlations, and previous foundation studies are clear and unambiguous. Given their negative views of our studies, we are curious to know why no direct comparisons were made with our data or sites? Il Fronte is the OIS 5e "type locality", lies within their study area, offers excellent stratigraphy, abundant corals and *Glycymeris* shells, and is a global stratotype for the Last Interglacial.

7. On their conclusions

Their Fig. 4 indicates a correlation of $R = 0.97$ between AAR and U-series data. A systematic problem of leaching of both the D-alloisoleucine and the ^{230}Th components from mollusks and coral could explain this odd correlation. This high correlation could also be explained by the exclusion of many unwanted data. The results from Hoang and Hearty (1989) show that leaching and migration of U and Th isotopes has rendered as useless U-series mollusk ages from Mar Piccolo. Results from the dryer climate of Mallorca were less seriously affected, although *still far from accurate*, ranging from OIS 5c to early OIS 5e (102–135 ka).

A higher-than-present sea-level highstand during OIS 3 in Mar Piccolo is highly improbable, even considering local tectonic effects (see Lambeck and Bard, 2000). Tectonic rates of nearly 1 m/ka would be required to lift the coastline the necessary 40–60 m to bring an OIS 3 sea level above present. With the exception of Reggio Calabria (Dumas et al., 1988), uplift rates of this magnitude have not been documented from the region. The conclusion that there is "no evidence of land emergence between OIS 5e and 5c" is not valid, as explained earlier in the text. Finally, we suggest that a >50-ka-long highstand between 140 and 90 ka, and a higher-than-present OIS 3 sea level at 48 ka based on mollusk U-series dates will be difficult to accept by the Quaternary science community.

References

Belluomini, G., Caldara, M., Casini, C., Cerasoli, M., Manfra, L., Mastronuzzi, G., Palmentola, G., Sanso, P., Tuccimei, P., Vesica, P.L., 2002. The age of Late Pleistocene shorelines and tectonic activity of Taranto area, Southern Italy. Quaternary Science Reviews 21, 525–547.

Bernat, M., Bousquet, J-C., Dars, R., 1978. Io-U dating of the Ouljian stage from Torre Garcia (Southern Spain). Nature 275, 301–303.

Bonifay, F., Mars, P., 1959. Le Tyrrhenien dans le cadre de la chronologie quaternaire Mediterranenne. Bulletin Societe Geologique Francaise, Series 7 1, 62–78.

Cita, M.B., Castradori, D., 1994. Workshop on marine sections from the Gulf of Taranto (Southern Italy) usable as potential stratotypes for the GSSP of the Lower, Middle and Upper Pleistocene. Il Quaternario 7 (2), 677–692.

Dai Pra G., 1995. Geochronology and stratigraphy of marine deposits of the Salentine Peninsula (Gulf of Taranto, Italy) as potential stratotypes for the GSSP of the Upper Pleistocene. Terra Nostra, INQUA, XIV International Congress. Abstract, p. 58.

Dai Pra, G., Stearns, C.E., 1977. Sul Tirreniano di Taranto: Datazione su coralli con il metodo del 230Th/234-U. Geologica Romana 16, 231–242.

Deperet, C., 1918. Essai de coordination chronologique de temps Quaternaire. Comptes rendus hebdomadaires de l'Academie des Seances, Paris 166, 480–486.

Doglioni, C., 1991. A proposal for the kinematic modelling of W-dipping subductions—possible application to the Tyrrhenian-Apennines system. Terra Nova 3, 423–434.

Doglioni, C., 1994. Foredeeps versus subduction zone. Geology 22, 271–274.

Dumas, B., Hearty, P.J., Guérémy, P., Lhénaff, P., Raffy, J., 1988. Morphometric analysis and amino acid geochronology of uplifted shorelines in a tectonic region near Reggio Calabria, south Italy. Palaeogeography, Palaeoclimatology, Palaeoecology 68, 273–289.

Gignoux, M., 1913. Les formations marines pliocenes et Quaternaires de l'Italie du sud et de la Sicilie. Annals de l'Universite de Lyon, n.s. 36.

Hearty, P.J., 1986. An inventory of last interglacial (s.l.) age deposits from the Mediterranean basin: a study of isoleucine epimerization and U-series dating. Zeitschrift für Geomorphologie, Supplement-Band 62, 51–69.

Hearty, P.J., Dai Pra, G., 1985. Aminostratigraphy and 230Th/234-U dating of Quaternary shoreline in the Puglia region of southern Italy. Proceedings of the Fifth International Coral Reef Congress, Vol.3. Papeete, Tahiti, pp. 163–169.

Hearty, P.J., Dai Pra, G., 1992. The age and stratigraphy of Quaternary coastal deposits along the Gulf of Taranto (south Italy). Journal of Coastal Research 8 (4), 882–905.

Hearty, P.J., Miller, G.H., Stearns, C.E., Szabo, B.J., 1986. Aminostratigraphy of Quaternary shorelines around the Mediterranean basin. Geological Society of America Bulletin 97, 850–858.

Hillaire-Marcel, C., Carro, O., Causse, C., Goy, J-L., Zazo, C., 1986. Th/U dating of *Strombus bubonius* bearing marine terraces in southern Spain. Geology 14, 613–616.

Hoang, C-T., Hearty, P.J., 1989. Uranium-series and amino acid dating comparisons from the "Il Fronte Formation" Puglia Italy, and Son Grauet, Mallorca, Spain. Chemical Geology (Isotope Geoscience Section) 79, 317–323.

Issel, A., 1914. Lembi fossiliferi quaternari e recenti nella Sardegna meridionale. Accademia Nazionale dei Lincei serie 5 23, 759–770.

Kaufman, A., Broecker, W.S., Ku, T.L., Thurber, D.L., 1971. The status of U-series methods of mollusk dating. Geochemica Cosmochemica Acta 35, 1155–1183.

Lambeck, K., Bard, E., 2000. Sea-level change along the French Mediterranean coast for the past 30,000 years. Earth and Planetary Science Letters 175, 203–222.

McLaren, S.J., Rowe, P.J., 1996. The reliability of uranium-series mollusc dates from the western Mediterranean basin. Quaternary Science Reviews 15, 709–717.

Roof, S., 1997. Comparison of isoleucine epimerization and leaching potential in the molluskan genera *Astarte, Macoma*, and *Mya*. Geochemica et Cosmochemica Acta 61, 5325–5333.

Stearns, C.E., Thurber, D.L., 1965. 230-Th/234-U dates of late Pleistocene marine fossils from the Mediterranean and Moroccan littorals. Quaternaria 7, 29–41.

Stearns, C.E., Thurber, D.L., 1967. 230-Th/234-U Dates of late Pleistocene marine fossils from the Mediterranean and Moroccan littorals. Progress in Oceanography 4, 293–305.

Szabo, B.J., 1979. 230Th, 231 Pa, open-system dating of fossil corals and shells. Journal of Geophysical Research 84, 4927–4930.

Westaway, R., 1993. Quaternary uplift of southern Italy. Journal of Geophysical Research 87, 741–772.

Zazo, C., 1999. Interglacial sea levels. Quaternary International 55, 101–113.

Zazo, C., Goy, J.L., Aguirre, E., 1984. Did *Strombus* survive the last interglacial in the Western Mediterranean? Mediterranea Serie de Estudios Geologicos 3, 131–137.