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Discontinuous metamorphic zonation in the Paleozoic units of the Hercynian chain of SW Sardinia, Italy: evidence from structural and illite crystallinity data

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Abstract

Two discontinuous metamorphic zonations have been recognized in the Paleozoic sequence of the external zone of the Hercynian chain of Sardinia by measuring illite crystallinity. The first metamorphic discontinuity coincides with an erosional angular unconformity ("Sardic Phase") between the epimetamorphic Cambrian-Early Ordovician (CEO) and the anchimetamorphic Ordovician-Early Carboniferous (OEC) sequence. The second metamorphic discontinuity was observed between the OEC sequence and the overlying epimetamorphic tectonic Arburese Unit. During the Ordovician, the CEO sequence was affected by locally penetrative deformation and epimetamorphism related to the tectonic evolution of a back arc basin. After the uplift, the CEO sequence along with the overlying OEC sequence were affected by Hercynian regional deformation and weak metamorphism typical of the outermost zone of the orogenic chain. The second metamorphic discontinuity is interpreted as "transported metamorphism" due to the overthrust of the internal allochthonous Arburese Unit on the OEC sequence of south western Sardinia during late Hercynian extensional tectonics.

Keyword: illite crystallinity, pelite, discontinuous metamorphic zonation, unconformity, overthrust, Hercynian orogeny, Sardinia, Italy.

Introduction

In the last twenty years several studies mainly based on illite crystallinity (IC) data revealed that discontinuous metamorphic zonations are common features of the external zones of collisional chains. These metamorphic discontinuities, that often coincide with tectonic contacts are thought to be the result of various geological mechanisms such as syn- to post-metamorphic thrusting, recumbent folds or shear heating (Frey, 1988; Spring et al., 1993).

Since the time of Stille (1939) an erosional angular unconformity (called the Sardic unconformity) has been recognized in the outermost zone of the Hercynian chain of Sardinia between the Ordovician-Early Carboniferous (OEC) and the underlying Cambrian to Early Ordovician (CEO) sequences. Another major structural discontinuity occurs between the outermost zone and the nappe segment of the chain. The latter structural discontinuity is a regional overthrust (Arburese overthrust) of the Arburese Unit on the OEC sequence (Fig. 1a).

The structural evolution of SW Sardinia is well known, but not much has been published on the metamorphic events affecting its Paleozoic rocks. First data on the metamorphism have been published by Conti et al. (1978) and Franceschelli et al. (1992). Anchimetamorphic grade was recognized in the "Puddinga" of the OEC sequence, and epimetamorphic grade in the Cabitza Formation (Fm) of the CEO sequence below the Sardic unconformity (Franceschelli et al., 1992).

This paper presents a large number of illite crystallinity data for pelitic rocks of SW Sardinia

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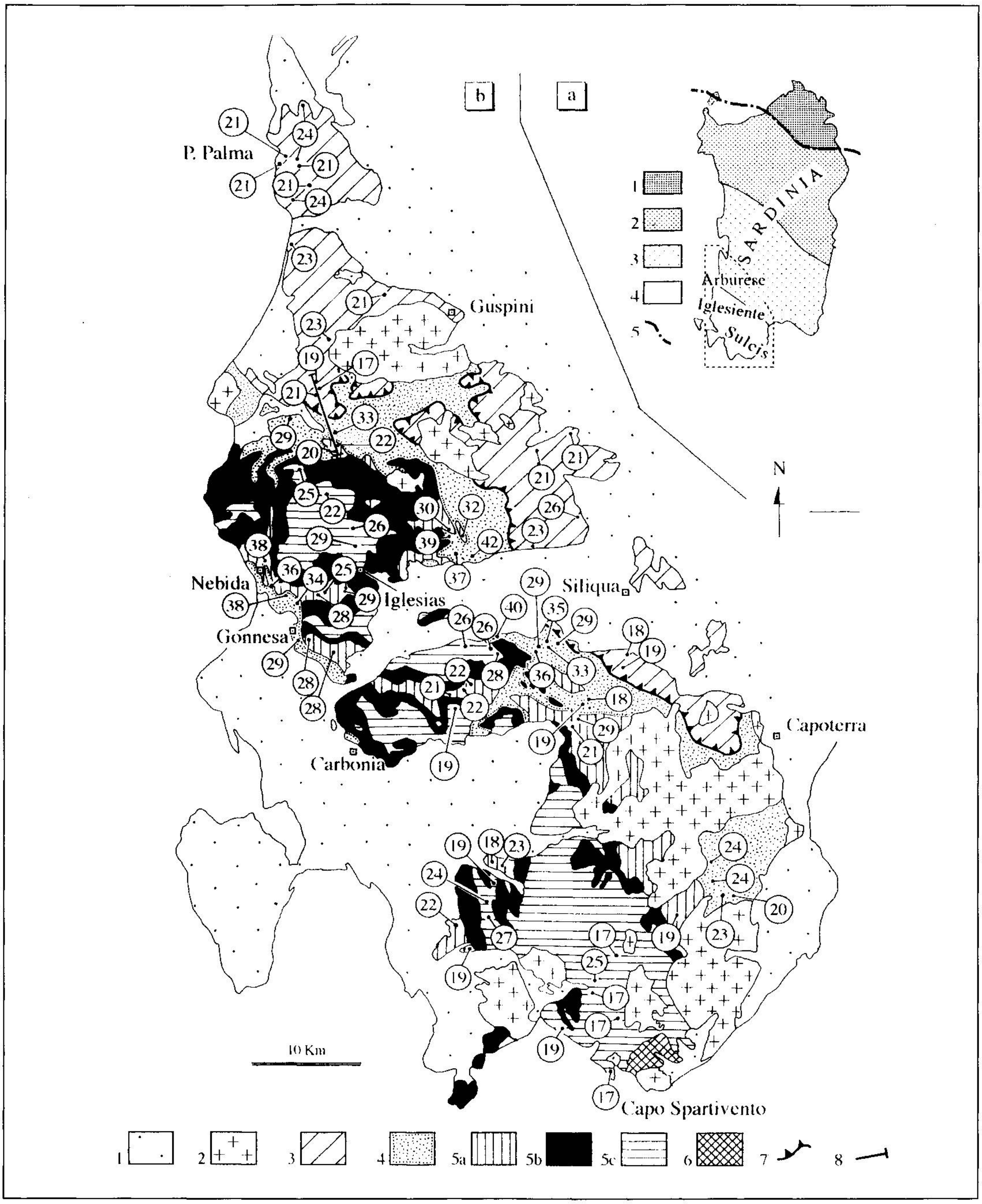

Fig. 1 Tectono-metamorphic subdivision of the Hercynian basement of Sardinia and geological sketch map of the South Sardinian Paleozoic basement (modified from CARMIGNANI et al., 1987) also showing the distribution of IC values (°Δ2Θ × 100). a). 1: High Grade Metamorphic Complex of the South-Armorica margin; 2: Internal Nappe Zone, 3: External Nappe Zone, 4: Outermost Zone of the North-Gondwana margin. b) 1: Post-Hercynian cover; 2: Hercynian granitoids; 3: Arburese Unit; 4: OEC sequence, 5: CEO sequence; 5a: Cabitza Fm; 5b: Gonnesa group; 5c: Nebida group and Bithia Fms; 6: Gneiss and micaschist of the Capo Spartivento complex ; 7: Arburese overthrust; 8: Trace of the cross section shown in figure 5 (see text for further explanations).

(Iglesiente and Sulcis) documenting two major discontinuous metamorphic zonations across the Sardic angular unconformity and the Arburese overthrust. It also tries to explain these discontinuous metamorphic zonations within a regional context.

Regional geology

The Hercynian chain of Sardinia is a complex tectonic pile of units built during the collision of the Armorica and the Gondwana plates. Four distinct tectono-metamorphic NW–SE trending zones have been distinguished within the Hercynian of Sardinia by CARMIGNANI et al. (1992), from north to south: 1) High-Grade Metamorphic Complex of south Armorican margin; 2) Internal Nappes Zone; 3) External Nappes Zone; 4) Outermost or External zone of the paleo-Gondwana margin (Fig. 1a). A geological sketch map of SW Sardinia is shown in figure 1b. The tectono-stratigraphical subdivisions of Paleozoic rocks of the Outermost zone and the Arburese Unit of the External Nappe zone are shown in figure 2. From bottom to top three units are defined:

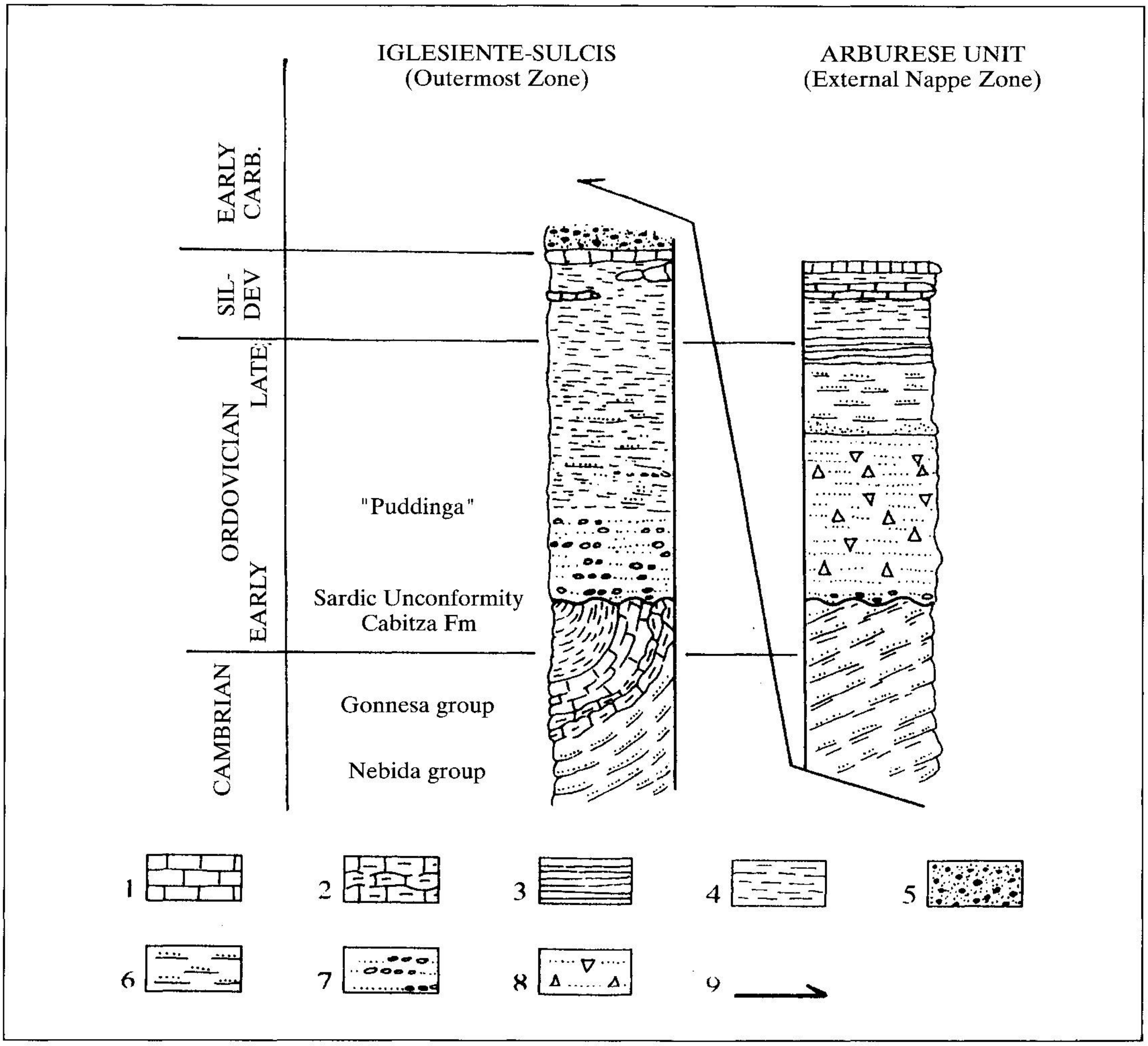

Fig. 2 Sketch showing the stratigraphic columns of the Paleozoic sequences of the Outermost Zone and the Arburese Unit along with their tectonic relationships. 1: Metalimestones; 2: Metadolostones; 3: Carbonatic metasiltites, slates and metalimestones of Upper Ordovician age; 4: Slates and phyllites; 5: Terrigenous flysch; 6: Metasandstones; 7: Metaconglomerates; 8: Metarhyodacites, metarhyolites and metamorphic products of reworked volcanites; 9: Tectonic contacts and vergence of overthrusts.

1) *CEO sequence.* The CEO sequence lies stratigraphically on the Bithia Fm of Lower Cambrian age, the latter tectonically on the complex of Capo Spartivento made up of the orthogneiss of Monte Filau, an Ordovician granitoid (COCOZZA et al., 1977; DELAPERRIERE and LANCELOT, 1989; LUDWING and TURI, 1989) which intruded in the micaschist of Monte Settiballas. According to the nomenclature of PILLOLA (1991) the CEO was subdivided from bottom to top: into Nebida, Gonnesa and Iglesias Groups, unconformably overlain by Ordovician sediments (Figs 1b, 2). The base of the Nebida Group is made up of an alternation of metasandstone, metasiltite and rare calcareous intercalations (Matoppa Fm) and the top consists of alternating metasandstone, metasiltite, phyllite and metalimestone (Punta Manna Fm). The Gonnesa Group is mainly composed of massive metadolostones and grey stratified metalimestone. The base of the Iglesias Group is made up of nodular crystalline limestone, (Campo Pisano Fm), and the top of phyllites and metasiltites, interbedded with minor massive fine-grained metasandstone (Cabitza Fm).

2) *OEC sequence.* From bottom upwards this sequence consists of the "Puddinga", followed by Silurian-Devonian metasediments and Early Carboniferous foredeep deposits. The "Puddinga" is made up of Middle Ordovician polygenic metaconglomerates with a red-violet silt or shale matrix. The upper part is characterized by red silt and shale with minute conglomerate intercalations. The Silurian metasediments consist of regularly alternating grey or black sandstones, siltites, shales (LEONE et al., 1991) and black carbonaceous shale with fossiliferous limestone lenses. The Devonian metasediments are made up of shales and finely-banded limestones with lenses of fossiliferous limestones (GNOLI et al., 1990).

3) Arburese unit: A volcano-sedimentary unit mainly composed of Cambro-Ordovician metasandstone, metasiltite and phyllite, middle-Ordovician metavolcanics, their reworked sedimentary products and Silurian-Devonian black slate and metalimestone (Fig. 2). Minor tectonic units within the Arburese Unit have been described recently by BARCA et al. (1992).

The following deformation history of the Paleozoic rocks of SW Sardinia has been reconstructed: 1) Sardic phase: open E–W trending folds, in the Arenig-Caradoc interval; 2) first Hercynian phase: E–W trending folds without any schistosity development; 3) second Hercynian phase: N–S trending folds associated with pervasive schistosity; 3) third Hercynian deformation including late local westward thrust and eastward backthrust (ARTHAUD, 1963; POLL and ZWART, 1966; CAROSI et al., 1992). Three systems of small scale structures (D_1, D_2, D_3) were recognized by MAZZARINI and PERTUSATI (1991) in the Arburese Unit. D_1 is associated with pervasive axial plane schistosity (S_1) and mineral growth. D_1 deformation is followed by important regional overthrust from NE to SW. The Hercynian age of the deformation of SW Sardinia is based on stratigraphic evidence by the occurrence of deformed and metamorphic Tournaisian rocks, while the upper Carboniferous rocks show neither orogenic deformation nor metamorphism.

Sampling and analytical methods

Sampling was performed based on the map of the "Structural model of the Hercynian basement of Sardinia 1 : 500.000" (CARMIGNANI et al., 1987) and of several detailed unpublished geological maps. For each of the chosen outcrops two to five representative pelitic samples were selected, giving a total of more than 400 samples (Fig. 1b). Care was taken to exclude outcrops with a clear evidence of contact metamorphism, weathering, hydrothermal circulation, or faulting. Sampling was intensified near the Arburese overthrust and Sardic unconformity. The following formations (or members) were investigated:

1) Cambro-Ordovician pelitic and quartz-pelitic rocks, and Silurian black pelitic rocks of the Arburese Unit;

2) pelitic, red and grey siltitic rocks and the fine-grained portion of the middle Ordovician "Puddinga" and Silurian-Carboniferous pelitic and siltitic rocks from the upper part of the OEC sequence;

3) pelitic and siltitic rocks of the Nebida Group, pelitic rocks of the Cabitza Fm from the CEO sequence.

IC data from about 100 samples of the Cabitza Fm, "Puddinga" and the Arburese Unit were given by FRANCESCHELLI et al. (1992). Only the first group was considered for the diagrams, while a few results from the second group of data were considered for the discussion.

Samples were dried and crushed using a ball mill, and sieved through a 0.5 mm sieve. The powder was then suspended in water and the aqueous suspension containing the $< 2\ \mu m$ grain-size fraction was pipetted onto glass slides and dried at 80 °C. The IC was determined by means of a fully automatic Rigaku Geigerflex diffractometer according to the procedure described by FRANCESCHELLI et al. (1991, 1994). The non metamorphic/anchimetamorphic ($\Delta°2\Theta$ = 0.42) and anchimetamorphic/epimetamorphic ($\Delta°2\Theta$ = 0.25) boundaries proposed by KÜBLER (1984) were assumed.

Results

X-RAY MINERALOGY

The main objective of the X-ray diffractometric work was to measure illite crystallinity (IC). Nevertheless all the oriented air-dried slides were routinely scanned from 2° to 35° 2Θ in order to determine the mineralogical composition of the < 2 μm fraction. Duplicate slides of many samples were glycolated, heated at 250 and 500 °C and then analysed. The mica polytypes were identified by the MAXWELL and HOWER (1967) method. The b_o spacing was calculated from the (006–331) peak of mica, using the quartz (221) reflection as an internal standard. Measuring was performed on randomly oriented samples of the < 2 μm fraction. For 50 samples of the CEO sequence the measurement of the b_o spacing was repeated on rock slabs cut parallel to the main foliation as recommended by GUIDOTTI and SASSI (1976).

The samples of the CEO sequence consist of quartz, white K-mica and chlorite and rarely paragonite. A mixed-layer tentatively attributed to chlorite/vermiculite was observed in two samples. No carbonate, albite and opaque minerals have been detected in the X-ray pattern though identified microscopically in thin sections. The b_o spacing in the samples of the Nebida Group ranges from 8.989 Å to 9.020 Å with an average value of 8.998 Å (n = 50). The b_o spacing in the samples of the Cabitza Fm ranges from 8.990 Å to 9.025 Å with an average value of 9.003 Å. In the investigated samples $2M_1$ is by far the most common polytype of K-white mica. Only in a few samples the 1Md polytype reached 20%.

The samples of the OEC sequence consist of white-K mica, chlorite, quartz, and minor paragonite and kaolinite. Mixed-layer minerals not clearly identified were observed in five samples. In thin section, carbonate, apatite, tourmaline and Fe-oxide are common components of the rock. In about 30 samples of the various units the $2M_1$ is the dominant polytype, 1Md polytype was calculated sporadically up to 30%. The b_o spacing ranges from 8.998 Å to 9.002 $Å_1$.

The < 2 μm fraction of the samples from the Arburese Unit consists of white K-mica, ± chlorite and quartz. The b_o of mica ranges from 8.999 Å to 9.020 Å. The average value is

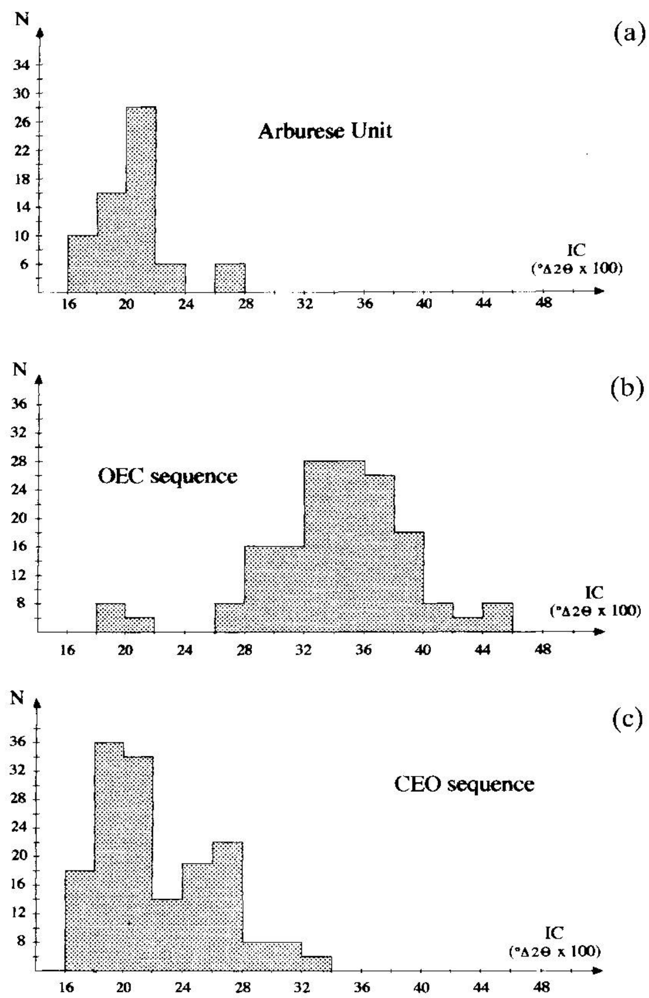

Fig. 3 Histograms showing the distribution of IC (°$\Delta 2\Theta \times 100$) values in the pelitic rocks of: a) Arburese Unit, b) OEC sequence, c) CEO sequence. N = number of samples (see text for explanations).

9.012 Å (n = 50). The $2M_1$ polytype ranges from 70 to 100 per cent.

Further mineralogical and petrographical data of the rocks from Nebida Group, Cabitza Fm, "Puddinga" and Arburese Unit can be found in PALMERINI et al. (1980, 1985) and CONTI et al. (1978).

ILLITE CRYSTALLINITY DATA

The sampled localities and their average IC values ($\Delta°2\Theta \times 100$) are shown in figure 1. Each value is the average of two to five samples; the standard deviation is always lower than ± 0.05. The following values were obtained (Fig. 3):

1) Arburese Unit: on a regional scale the IC values range from 0.17 to 0.28 $\Delta°2\Theta$ with a cluster of values from 0.18 to 0.22 $\Delta°2\Theta$.

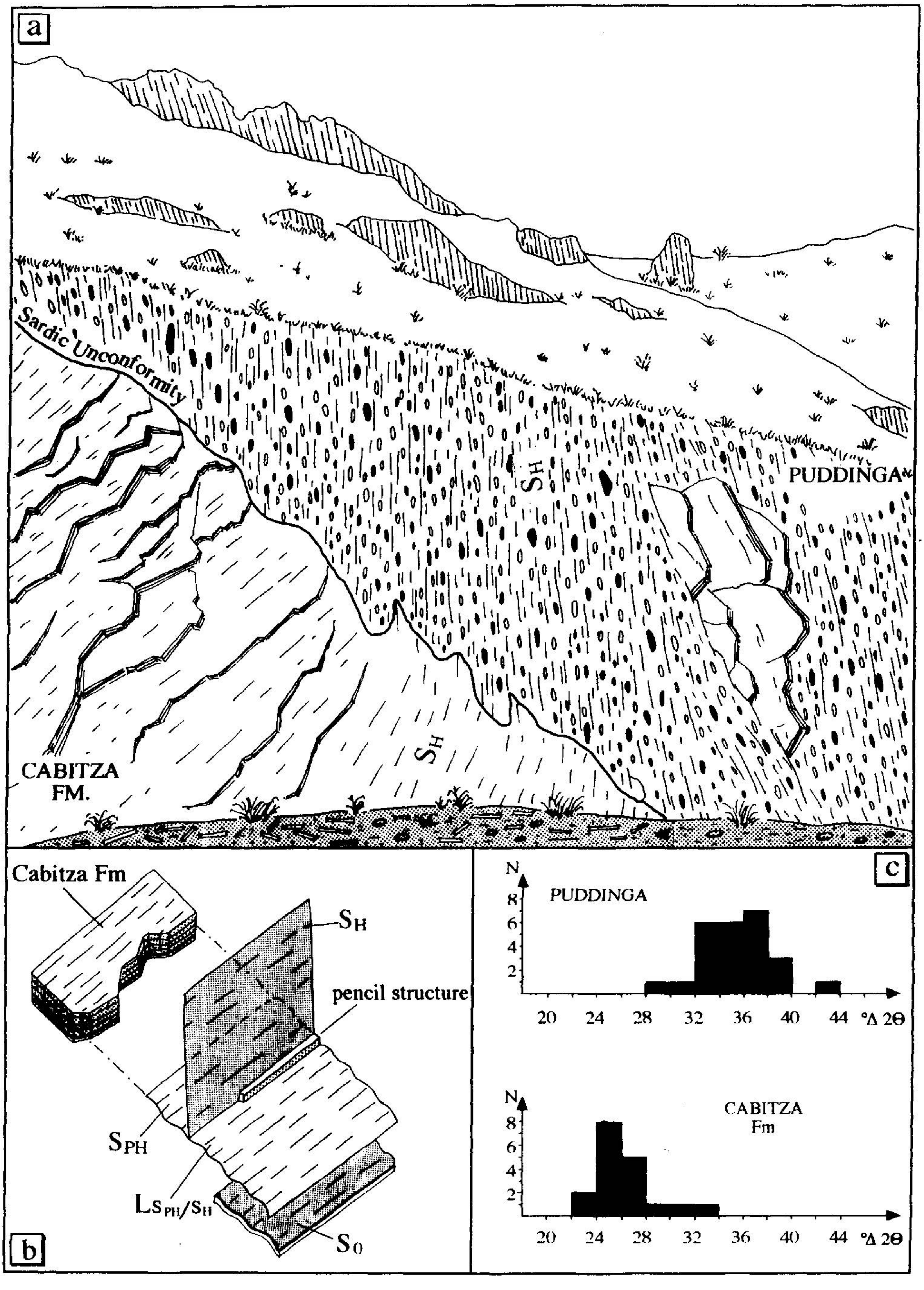

Fig. 4 Sketch showing the structural relationships at the Sardic angular unconformity between the Cabitza Fm (OCE sequence) and the overlying "Puddinga" (CEO sequence): a) sketch of the Sardic angular unconformity about 1 km south of Nebida village. b) Relationships among structural elements. c) Histograms showing the distribution of IC (°Δ2Θ × 100) values in the pelitic rocks of the "Puddinga" and Cabitza Fm collected near the unconformity. Abbreviations: S_0: bedding; S_H: Hercynian schistosity, S_{PH}: pre-Hercynian schistosity, LS_{PH}/S_H: Intersection between S_H and S_{PH} schistosities; N = number of samples (see text for explanations).

2) OEC sequence: This shows values in the range 0.26–0.45 Δ°2Θ with a cluster of values from 0.32 to 0.38 Δ°2Θ. Lower IC values of 0.18–0.22 Δ°2Θ were observed in a locality SW of Siliqua. All the stratigraphic units of this sequence were affected by anchizonal conditions. No regionally or stratigraphically related differences occur.

3) CEO sequence: IC values in the Nebida Group range from 0.17 to 0.26 Δ°2Θ. No significant differences have been obtained between samples of Matoppa and Punta Manna Fms (Fig. 1a). IC values in the Cabitza Fm fall in the range 0.19–0.34 Δ°2Θ, with a cluster of values at 0.24–0.27 Δ°2Θ. The IC values of the pelitic rocks of the Cabitza Fm are generally higher than the IC values measured in the rocks of the Nebida Group. Higher values of 0.28–0.34 Δ°2Θ are locally observed along the Iglesias-Nebida road.

IC at the Sardic unconformity: A cartoon depicting the field relationships between the bottom of the OEC sequence ("Puddinga") and the top of the CEO sequence (Cabitza Fm) is shown in figure 4. The Cabitza Fm and the "Puddinga" as well as the erosional unconformity surface were affected by a N–S Hercynian fold system associated with an axial plane schistosity (S_H in Fig. 4a). The lithological contrast between the Cabitza Fm and the "Puddinga" rocks produced round shaped synforms and antiforms and a refraction of the S_H schistosity. In the rocks of the Cabitza Fm the S_H Hercynian schistosity can be traced easily. The S_H Hercynian schistosity cuts a roughly pre-Hercynian E–W foliation (S_{PH}) generally parallel to the bedding (S_0). The roughly normal strike between the Sardic phase and Hercynian foliation, produced crenulations in the older one, and very pervasive pencil cleavage structures (Fig. 4b). On the basis of microstructural relation, we have selected, samples mainly characterized by S_H and S_{PH} schistosities just above and below the Sardic unconformity along the Iglesias-Nebida road. The IC values obtained for these two groups of samples are presented in the histograms in figure 4c. IC from the rocks of the Cabitza Fm range from 0.22 to 0.34 Δ°2Θ with a cluster of values between 0.24 and 0.28. Locally the Cabitza Fm, along the Sardic unconformity, shows IC values up to 0.34 Δ°2Θ. IC in the "Puddinga" varies from 0.28 to 0.44 Δ°2Θ with a cluster of values of 0.32–0.38 Δ°2Θ. IC values are comparable with those obtained in samples from other outcrops of the CEO and OEC sequences.

IC at the Arburese overthrust: The Arburese overthrust is a regional overthrust with a NW–SE trend. It is easily followed for about 30 km, but offers the opportunity of detailed sampling only in few localities. In one of these, Fluminimaggiore, we performed detailed sampling along a NNW-SSE section (Fig. 1b). The localization of the sample sites along with the tectonic relationships between the CEO sequence, the OEC sequence and the Arburese Unit, are shown in the schematic geological cross section in figure 5. The

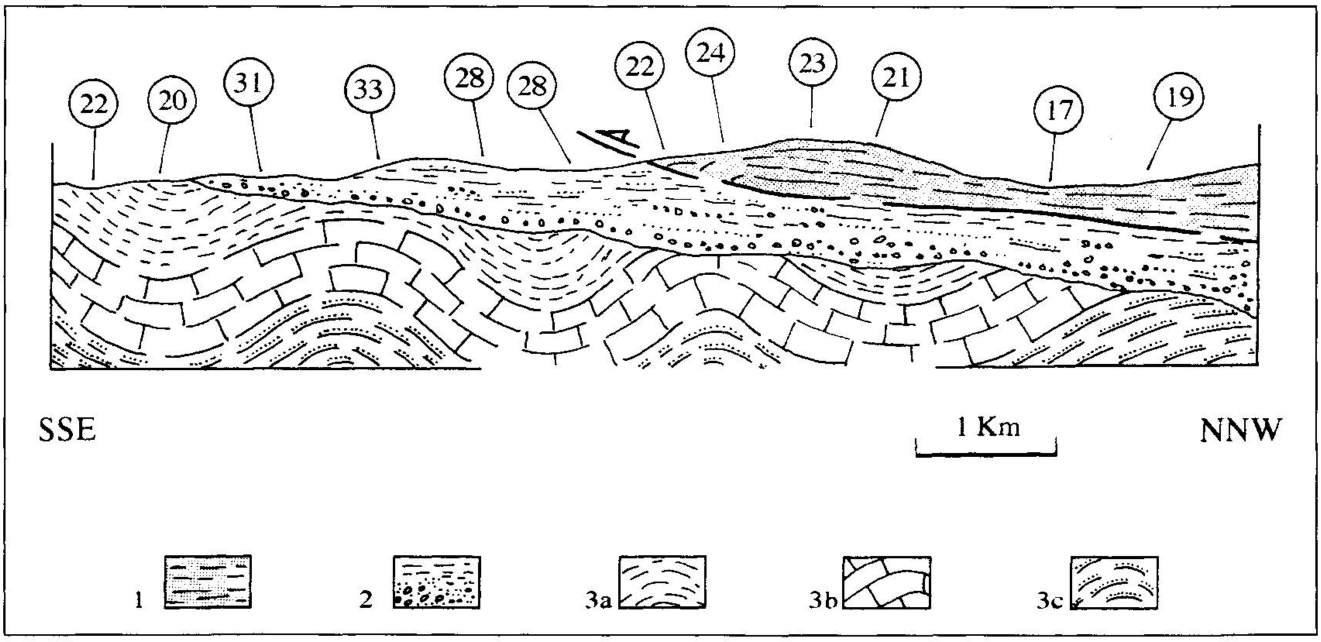

Fig. 5 Shematic geological cross section (for location see Fig. 1a) through the Arburese overthrust showing also the Sardic Unconformity. 1: Arburese Unit; 2: OEC sequence; 3) COE sequence; a: Cabitza Fm, b: Gonnesa group, c: Nebida group.

samples collected in the Arburese Unit and the OEC sequence are quartz pelitic rocks moderately to strongly schistose. The most common S_1 mineral assemblage is white K-mica, quartz and chlorite. Detrital muscovite is often present but in very low modal proportions and its effects are probably negligible in the < 2 μm fraction. Mineral crystallization along the S_2 schistosity is scarce or absent. The Arburese overthrust has an attitude nearly parallel or at a low angle with the regional S_1 schistosity that trends NE–SW and dips towards SE in this area. Several field examples show that the Arburese overthrust cuts the D_1 fold structure.

In the southern part of the section, below the OEC sequence, the Cabitza Fm of the CEO sequence crops out. Unfortunately the Sardic unconformity in not clearly visible here. Therefore the structural relation between the "Puddinga" and the Cabitza Fm rocks cannot be reconstructed in detail. The two cleavages observed in samples of the Cabitza Fm can be tentatively attributed to the Hercynian and pre-Hercynian schistosity.

IC values in the Arburese Unit range from 0.17 to 0.24 $\Delta°2\Theta$. In the underlying OEC sequence the IC values range from 0.28 to 0.33 $\Delta°2\Theta$ and in the OCE sequence from 0.20 to 0.22 $\Delta°2\Theta$.

Discussion

COMMENT ON IC DATA

IC values obtained from samples of the various formations are clearly grouped according to their geometrical position in the Paleozoic sequence of SW Sardinia (Fig. 3). A general vertical increase in IC values characterizes the transition from the lowermost CEO sequence (epizone and epizone-anchizone transition) to the overlying OEC sequence (anchizone), followed by a decrease in the overlying Arburese Unit (epizone).

As pointed out in previous studies (FREY, 1987), lithology may play an important role in determining IC values. There are three main lithological differences in the studied samples: the occurrence of carbonate, mainly in the Cabitza Fm, the colour (red or grey) in rocks of the OEC sequence; and the presence of paragonite.

A systematic study of the samples with these lithological differences in each formation seems to suggest that these factors do not play a relevant role in determining the IC values. For instance, a complete overlap of IC values has been observed in the red or grey siltite of the OEC sequence as well as in carbonate-free or carbonate-bearing samples of the Cabitza Fm. Special attention was devoted to the presence of paragonite. In significative amounts this mineral proved to be a disturbing factor in the accuracy of IC determination. In the studied rocks paragonite is always a minor component; furthermore paragonite-free and paragonite-bearing samples show a complete overlap of IC values.

Metamorphic conditions in rocks of the Outermost Zone and the Arburese Unit are scarcely known. A temperature estimate of 300–400 °C and a low pressure character of metamorphism has been suggested by SASSI (1981) for rocks from the bottom of the CEO sequence (Nebida Group). On the basis of mineral assemblages, textures of pelitic rocks and X-ray characteristics of white K-mica, CONTI et al. (1978) suggested high diagenetic P-T conditions for the "Puddinga" of the OEC sequence. Finally, the metamorphic grade of the rocks of Arburese Unit has been referred to greenschist facies by MAZZARINI and PERTUSATI (1991).

In conclusion, the IC values observed in the Arburese Unit and in the OEC and CEO sequences seem to be a good indicator of metamorphic grade. The increase in IC values in the lower part of the CEO sequence may be interpreted as an increase in the degree of metamorphism in the lower part of the CEO sequence. The contrast between the epizone or epizone-anchizone transition IC values of the CEO sequence and the anchizone IC values of the overlying OEC sequence as well as the occurrence of a pre-Hercynian schistosity which was not found in the rocks of the OEC sequence, are the first hints for an Ordovician metamorphism in the rocks of the Outermost Zone.

Anchizonal metamorphism in the OEC sequence and epizonal metamorphism in the Arburese Unit were achieved during the main Hercynian (D_1) compressional deformation. This is proved by IC values of mica oriented parallel to the S_1 schistosity and by the fact that no significant mineralogical crystallization along the S_2 schistosity was observed. Furthermore, the sharp increase in IC values coinciding with the tectonic contact between the two units suggests that the Arburese Unit has a different Hercynian metamorphic history with respect to the rocks of the OEC sequence from the Outermost Zone.

GEOLOGICAL INTERPRETATION

In the Sulcis and Iglesiente there is evidence of Middle Ordovician E–W large scale folding that

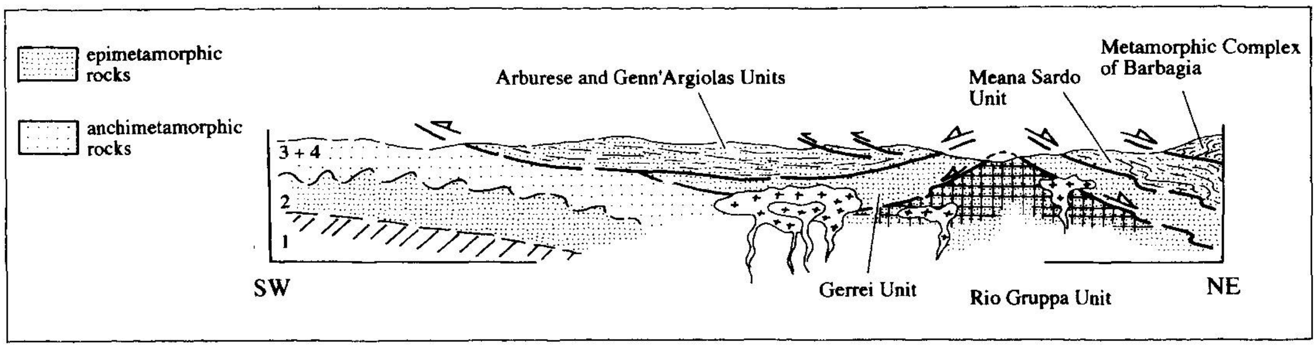

Fig. 6 Schematic cross section showing the metamorphic zonation and framework of the Hercynian basement of Central and Southern Sardinia (after CARMIGNANI et al., 1992 modified). 1: Pre-Paleozoic basement; 2: CEO sequence; 3: OEC sequence; 4: Hercynian foredeep deposits. Black arrow: movement during the compressional event. White arrow: movement during the extensional event.

has been related to the Sardic phase (ARTHAUD 1963; POLL and ZWAR, 1964). The fold characteristics and the foliation, which is generally parallel to the bedding, are indicative of low structural thickening in the pile of Cambrian-Early Ordovician sediments. This implies that the burial and shortening produced by the Sardic phase could not have caused the epimetamorphism in the Cambrian-Ordovician sediments of the Sulcis and Iglesiente.

Another relevant aspect is the decrease in IC values from the Cabitza Fm to the Matoppa Fm of the Nebida Group that indicates a clear metamorphic zonation. The Cabitza Fm has a tickness of max. 400 m and this stratigraphical burial could not explain the observed metamorphic zonation.

According to MARTINI et al. (1991), CARMIGNANI et al. (1992) in the Upper Cambrian, the Iglesiente-Sulcis represented the northern margin of the Gondwana plate that, evolved in a back-arc basin in the Lower Ordovician. In the Middle Ordovician the CEO sequence was involved by a shortening phase that caused moderate crustal thickening, and development of E–W trending open folds. The uplift of the CEO sequence, and its consequent erosional surface was unconformably covered by the basal clastic sedimentation of the OEC sequence.

The metamorphism and the related metamorphic zonation of the CEO sequence may have been caused by a high geothermal gradient, associated with the lithospheric thinning typical of the rifting region that evolved subsequently in a back-arc basin and/or by the heat flux due to the magmatic activity that occurred in the region at 478 ± 16 Ma (DELAPERRIERE and LANCELOT, 1989).

In the Late Ordovician the basal clastic sedimentation of the OEC sequence was followed northwards by the domains of sedimentation of the deeper tectonic units of the External Nappe zone (Riu Gruppa, Gerrei Units) and of the Arburese and related units (Meana Sardo and Genn' Argiolas Units) (FRANCESCHELLI et al., 1992). The sedimetation in these domains continued up to the Early-Carboniferous shortening related to the Gondwana and Armorica collision. This deformation produced an antiformal stack-shaped nappe pile in Central Sardinia (CARMIGNANI et al., 1992), in which the outermost Riu Gruppa and the Gerrei Units were buried deeper than the innermost units (Fig. 6).

The overthrust nappe structure, the polyphasic deformation and the metamorphism grade of the Arburese Unit are strictly correlated and analogous to those known in other units of the External Nappe zone in central and southeast Sardinia.

The increase in Hercynian metamorphic grade between the EOC sequence and the Arburese Unit indicates an increase in metamorphic grade during the early stage of the Hercynian deformation from the Outermost to the Nappe zone. Yet, in the antiformal stack-shaped nappe pile, the increase in metamorphic grade from the upper to the lowermost units, was revealed by pelitic S_1 mineral assemblages, i.e. occurrence of biotite in the rocks of the lowermost tectonic unit (Riu Gruppa Unit) and by IC data on S_1 muscovite given by FRANCESCHELLI et al. (1992).

According to CARMIGNANI et al. (1992) late Hercynian extensional tectonics played an important role in determining the structural framework of the Sardinia chain. Extensional tectonics dismembered the antiformal stack-shaped nappe pile and the tectonic discontinuity related to the D_1 compressional event, such as thrust and fault, were reworked causing, among others, southward post-metamorphic translation of the Arburese Unit over the CEO sequence and consequently inverted metamorphic zonation (Fig. 6). Obviously during the Early Carboniferous, the CEO sequence was newly deformed and metamorphosed together with the EOC sequence, but the Hercynian metamorphism and deformation did not destroy the "good crystallinity" acquired by mica during Ordovician metamorphism.

Conclusions

In the Paleozoic rocks of SW Sardinia, IC data show an increase in metamorphic grade from the lowermost CEO sequence (epizone) to the overlying OEC sequence (anchizone), followed by an increase in the overlying allochthonous (epizone) Arburese Unit. The discontinuities in metamorphic grade coincide with the Sardic angular unconformity and the Arburese overthrust. This complex metamorphic zonation seems to be due: a) to an Ordovician metamorphism that affected the rocks of the CEO sequence under relatively high geothermal gradient that occurred in a back-arc basin geodynamic framework and b) to a progressive Hercynian metamorphism from anchizone to epizone from the Outermost (i.e. OEC sequence) to the External Nappe zones (Arburese Unit) during the thickening stage of the Hercynian chain. Post-metamorphic southward translation of the epimetamorphic Arburese Unit of the External Nappe zone on the anchimetamorphic OEC sequence during the late Hercynain extensional tectonics produced regional inverted metamorphic zonation.

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