GEOLOGICA BALCANICA, 28. 3-4, Sofia, Decemb. 1998, p. 173-179

Geosites inventory in the Palaeozoic karst region of Sulcis-Iglesiente (South-West Sardinia, Italy)

Jo De Waele, Felice Di Gregorio, Giuseppe Piras

Dipartimento di Scienze della Terra, Via Trentino 51, 09127 Cagliari, University of Cagliari - e-mail digregof@vaxca.1.unica.it

Abstract. The South-western part of Sardinia is characterised by exposure of Palaeozoic sediments representing the oldest rocks in Italy. Approximately a quarter of this area, named Sulcis-Iglesiente, is occupied by Cambrian sequences, reaching a visible thickness of over 2000 metres. One third of the Cambrian rocks is constituted of limestones and dolomites, intensely mineralised and karstified, forming one of the most interesting karstic areas of Europe.

In the present paper the authors have described 24 karstic geosites of particular interest, of which 16 in the Iglesiente area and the remaining 8 in Sulcis. These can be classified as caves (9), karst landscapes (7), karstic springs (4), paleokarst and mineralisation phenomena (4).

De Waele, J., Di Gregorio, F., Piras, G. 1998. Geosites inventory in the Palaeozoic karst region of Sulcis-Iglesiente (South-West Sardinia, Italy). - *Geologica Balc.*, 28, 3-4; 173-179

Key words: Sardinia, Cambrian, Limestones, Karst, Geosites

Introduction

The definition of Geosite (in Italian "Monumento Geologico o Geomorfologico") by Barca, Di Gregorio (1991) comprises elements of the landscape that possess particular characteristics, corresponding to significant genetic features (lithology, morphology, structure, etc.) or exhibit evident scientific, cultural or aesthetic value. The classification and the description of many geosites in Sardinia has been performed afterwards, bringing a valid contribution to the geographic and geologic knowledge of the Island.

In the present study the authors present twenty-four geosites of the karstic region of Sulcis-Iglesiente, in the South-western part of the Island, including only features that have a karstic genesis (caves, karst springs, carbonatic landscapes and paleokarstic mineralisations). All these geosites have been identified, studied and described by means of schedules, according to Barca, Di Gregorio (1991).

Geology of Iglesiente-Sulcis

Sardinia is characterised by the exposure of granitic and metamorphic rocks covered by sediments and volcanic deposits of different ages. The oldest outcrops are located in the south-western part of the island and are represented by schists, limestones and sandstones of the Cambrian System. This sequence, that reaches a thickness of at least 2000 metres (Civita et al., 1983), is confined to the top by the angular unconformity of the "Sardic phase", that separates these older sediments from the younger Ordovician clastics (Fig. 1).

The geographical area known as Sulcis-Iglesiente covers a surface of more than 2500 square kilometres and is bordered to the Northeast by the important graben structure of the Campidano, and on all other sides by the Tyrrenian Sea.

In general the topography is characterised by two massifs, the Northern one culminating on the granitic Mount Linas chain (1236 m), and the Southern one, more fragmented, with its highest point at the granitic Mount Is Caravius (1116 m). These two principal massifs are separated by the tectonic graben structure on which the E-W oriented Cixerri-valley is developed.

The Cambrian sequence starts with prevalently terrigenous fossiliferous sediments of the Nebida Group, subdivided in the lower Matoppa Formation and the overlying Punta Manna Formation, the latter

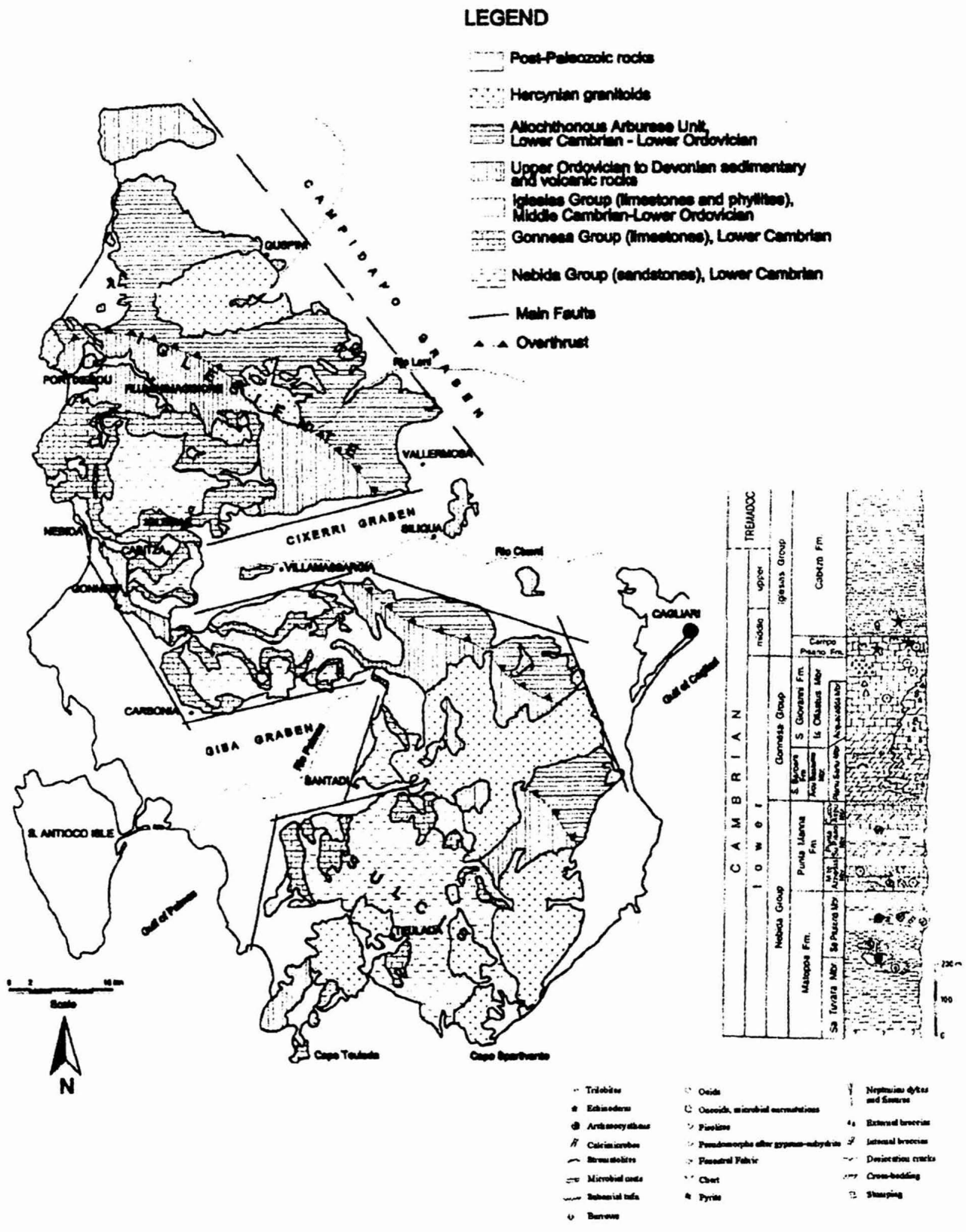


Fig. 1. Geological scheme and stratigraphical column of Sulcis-Iglesiente geology (modified from Bechstadt, Boni, 1996).

with intercalations of limestones, followed by the carbonatic platform succession of the Gonnesa Group composed from the bottom to the top of the Santa Barbara and the San Giovanni Formations. These Formations, also called with the general term "Metallifero", are the seat of very important lead-zinc mineralisations, exploited until recently. Upon these sediments, of Lower Cambrian age, are deposited nodular limestones of the Campo Pisano Formation (Middle Cambrian) followed by finely laminated terrigenous clastics of the Cabitza Formation, both included in the Iglesias Group of Middle Cam-

brian to Early Ordovician age. These depositional phases are followed by a long period of continentality, during which takes place the first karstic cycle.

The Cambrian sequence has been affected by three orogenetic cycles (Caledonian "Sardic phase", Hercynian, Alpine), showing complex structures that are the result of the superposition of different tectonic deformations (Civita et al., 1983; Bechstadt, Boni, 1996).

These Cambrian sediments are covered by younger Palaeozoic clastics of Ordovician, Silurian and Devonian age. This sequence starts with the so-called shallow water reddish and unfossiliferous "puddinga", reaching a thickness of over 300 metres (Monte Argentu Formation), followed by 100-150 metres thick marine finer clastic sediments (Monte Orri Formation) gradationally changing to the top in darker grey shales of the Portixeddu Formation, all of which rich in fossils. The Ordovician sequence ends with the sandstones and marly sediments of the Domusnovas Formation and the volcanoclastic and turbiditic Rio San Marco Formation, the upper part of which have probably an Early-Silurian age (Bechstadt, Boni, 1996). During the Devonian are deposed deeper water clastic and carbonatic sediments, of which remain some residual and incomplete outcrops in different parts of the region.

The Hercynian orogenic phase was followed by a long continental period that left traces from Late Carboniferous, Permian and Triassic age, particularly preserved in some paleokarst. In this new environmental situation, during Late Carboniferous-Early Permian times, an extended shallow water basin is formed with the deposition of plant remains (San Giorgio Formation). To the late Hercynian phases is to be connected the intrusion of the granitic batholites with related contact metamorphism and hydrothermal mineral depositions. Two important marine transgressions are documented during Triassic and Eocene times. The first one only partially has touched the region, leaving incomplete and limited sequences. Tertiary however is characterised by mainly continental formations and volcanic rocks that partly cover the earlier formations and by an important karstic phase (Civita et al., 1983).

Karst phenomena

The most characteristic landscape features of the Sulcis-Iglesiente area are represented by the dolomitic and limestone facies in which karst phenomena such as caves, canyons, sinkholes and various microforms are very well developed (Forti, Perna, 1982). Karst includes mineralisation as well, and different lead-zinc and barite mines of the region have exploited paleokarst fillings of Tertiary, Permo-Triassic and/or Cambro-Ordovician age (Padalino et al., 1972; Boni, 1982).

The mining activity, that started as soon as in Cartaghinian age, has left deep traces in the landscape, with steriles, abandoned mining villages, mining pits and laveries, open pits, mining harbours and railways. Also vegetation has been influenced by these intense activities, the wood being used for armery and mineral-roasting, leaving wide desert plains.

The most interesting karst area is the Iglesiente massif, especially near the villages of Iglesias, Domusnovas, Fluminimaggiore and Buggerru, in which are actually known over 700 natural cavities (Forti, Perna, 1982) such as the Su Mannau cave with 8 km of development, the San Giovanni cave, unique example of natural tunnel entirely visitable by car, and the monumental Santa Barbara cave, with its barite crystals and calcitic concretions having its only entrance in the mining galleries. At the base of the carbonatic massif are located among the biggest karst-springs of Sardinia, such as Pubusinu and San Giovanni.

Karst in the Sulcis-area is more fragmented, being known about 20 little carbonatic outcrops, some of which have important caves and karst-springs, these last often with their relative travertine deposits. The most interesting features can be seen near the villages of Santadi, Nuxis, Villamassargia, Narcao and Carbonia. The Is Zuddas cave, among the most beautiful of Sardinia, is visited every year by more than 50.000 visitors, and is particularly appreciated because of the abundance of aragonite excentriques.

The geosites

Twenty-four geosites of the karstic region of Sulcis-Iglesiente, of which sixteen in the Iglesiente area and the remaining eight in Sulcis, including only features that have a karstic genesis, are described, using a schedule previously proposed and successively modified by Barca, Di Gregorio (1991) (Fig. 2). These can be classified as caves, karst landscapes, karstic springs, paleokarst and mineralisation phenomena. In Table 1 the list of these Geosites with their qualifying elements, global value and importance is given, while their location can be better understood in Fig. 3.

From the nine caves described, only two are open to public (Su Mannau and Is Zuddas) and account for more than 70000 paying visitors every year. These show caves are famous for their fine concretions and excentriques (Curreli et al., 1992). Other two caves, San Giovanni and Santa Barbara, have been proposed for a touristic development, the first being entirely visitable by car on a tarmac road that passes the natural cave gallery through the mountain for 800 metres, the latter known for its barite cristallizations, its huge calcite flowstones and its artificial entrance in an abandoned mining gallery (Forti, Perna, 1981).

The Su Benatzu and Sa Folla caves are worth protecting for their great archaeological interest, the

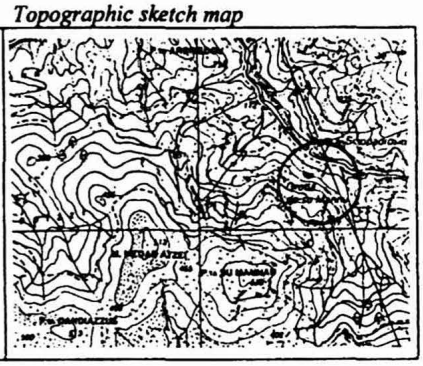
GROTTA DI SU MANNAU	Geosite	1

1. IDENTIFICATION

Location

- *Province* **Cagliari**
- *County* **Fluminimaggiore**
- *Locality* **Su Mannau**
- *Cartographic References:* I.G.M. 1:25.000 Sheet (1995): **546 II Gonnosfanadiga**
- *Metric Co-ordinates* (U.T.M.): **32 S MJ 5640 6230**

Topographic sketch map



Degree of knowledge

- *At scientific level:* not identified-identified-**studied** - *At general level:* ignored-little known-**known**

2. DESCRIPTION

Geologic characteristics:
Su Mannau cave is situated at about five kilometres south of Fluminimaggiore town and opens in ceroid limestones of the San Giovanni Formation (Gonnesa Group, Lower Cambrian). The cave is a karstic resurgence, in which unite two different underground rivers, both captured for civil uses by the aqueduct of Fluminimaggiore.

Geomorphologic characteristics:
Karstic cave complex constituted of three different parts, of which two are permanently occupied by an underground river. There are big rooms connected by long galleries and several pits, for an entire length of 8300 meters. In the most remote rooms it is still possible to observe beautiful aragonitic and calcitic flowstone formations that make the cave among the most beautiful of the entire region.

Cultural and/or naturalistic features in the monument or in the immediate surroundings:
The entrance room of the complex has a great interest from an archaeological point of view, because of the finding of late Neolithic and especially roman and Phoenician artifacts, donations done by the populations in relation with the presence of water (particularly lamps and coins). In the more distant underground chambers have been discovered several species of cave dwelling fauna, new for science and known only from this cave. Finally, Su Mannau is very important for the presence of the most astonishing concretions in different parts, going form the banal stalactites to the excentriques, abundant cave pearls and rare blue aragonites.

Qualifying elements:
Scientific interest, beauty, presence of drinking water, dimension.

Fig. 2. File card of the Geosite number 1, the show cave of Su Mannau.

small Breccia Ossifera cave has a scientific interest (Ulzega, 1968) while the Riomurtas resurgence is important for its cave dwelling fauna and its particular morphology. Another interesting cave system is the Cuccuru Tiria-Lago-Sesta-Torpado complex, over 5 km long and situated in the calcareous hills of Corongiu de Mari. This karst-system represents great archaeological, geological and biological valence (Chessa et al., 1994; Albaet et al., 1996).

Seven karst landscapes are described, representing the main geomorphologic features of this region (sinkholes, lapies, karst valleys, etc...). Even though they do not represent the most beautiful karstic morphologies of Sardinia, some of them are worth protecting for their peculiarity. These are the sinkholes and lapies of Corongiu de Mari (Albaet al., 1996), the collapse sinkholes, pits and dolines of Corona Arrubia (Ulzega, 1968), the spectacular collapse sinkhole of Mont'Ega (Corona et al., 1983), the karstic Canyon of Rio Sa Duchessa, and the karstic massifs of Punta Sèbera, Monte Tamara and Monte Acqua, the last one showing parakarst phenomena in the quartzitic veins.

The four most important karstic springs chosen for this work are San Giovanni, Sciopadroxiu de Pubusinu, Caput Acquas and Gran Sorgente. San Giovanni spring is used since prehistory, and from here probably started the acqueduct of Karalis, ancient Cagliari. Its mean flow rate is among the most abundant in this part of the island (100 l/s), even though less than the Pubusinu spring (250 l/s). Both springs have flowrate peaks of more than a cubic metre a sec-

3. CLASSIFICATION

Genetic classification	*Genetic definition*
Karstic	**Karstic Cave**

4. EVALUATION

Evaluation parameters		**Qualitative-quantitative value**			
		Weight = 1	Weight = 2	Weight = 3	Weight = 4
Principal	Evolutive exemplarity of the geosite	Discrete	Relevant	High	**Very High**
	Scientific valence	Discrete	Relevant	**High**	Very High
	Educational exemplarity	Discrete	Relevant	High	**Very High**
	Dimension	Significant	Distinct	Relevant	**Rare**
	Naturality of the site	Sufficient	Fair	Discrete	**High**
	Scenic intrinsic valence	Discrete	Relevant	High	**Very high**
	Occurrence on a geographic scale of the site	Frequent	Not frequent	Rel. rare	**Rare**
	Accessibility	Difficult	Discrete	**Good**	Very good
Integrative	Biologic valence	Discrete	Relevant	High	**Very high**
	Historical-cultural valence	Discrete	Relevant	High	**Very high**
	Panoramical valence	Discrete	Relevant	High	**Very high**
Global value of the geologic-geomorphologic monument		= $\sum$ Values		= **42**	
Importance at a geographic scale (On the base of the global value and on the rareness)		Local	Regional	**National**	International

5. USE AND PROTECTION

Actual use of the geosite and of the surrounding territory:
Touristic show cave with tourist accommodations, open to public during the whole year.
Possible human impacts on the environmental situation:
Possible great constructing operations (hotels and/or restaurants) and relative forest tailings.
Existing protection:
Closure by a fence, touristic management.
Proposal of conservation and valorisation:
Improve monitoring system of the show cave.

6. ESSENTIAL REFERENCES

Alba L. (1982) - I depositi archeologici nelle grotte dell'Iglesiente. in Le cavità naturali dell'Iglesiente, Memorie dell'Istituto Italiano di Speleologia, Serie II, Volume 1, pp. 35-42.
Argano R. (1973) - Trichoniscidae della grotta di Su Mannau, Sardegna Sud-Occidentale (Crustacea, Isopoda). International Journal of Speleology 5, pp. 153-162.
Argano R., Rampini M. (1973) - Note sulla distribuzione dei Trichoniscidae in Sardegna (Crustacea, Isopoda, Oniscoidea). International Journal of Speleology 5, pp. 311-317.
Bechstadt T., Boni M. (1996) - Sedimentological, stratigraphical and ore deposits field guide of the autochtonous Cambro-Ordovician of Southwestern Sardinia. Memorie descrittive della Carta Geologica d'Italia, Volume 48, 390 p.
Forti P., Perna G. (1982) - Inventario delle cavità dell'Iglesiente. in Le cavità naturali dell'Iglesiente, Memorie dell'Istituto Italiano di Speleologia, Serie II, Volume 1, pp. 55-229.
Furreddu A., Maxia C. (1964) - Grotte della Sardegna. 567 p.
Grimandi P. (1969) - Su Mannau 1969. Sottoterra 24, pp. 22-25.
Pappacoda M. (1982) - La grotta di Su Mannau. Speleologia 7, pp. 7-8.
Puddu S., Pirodda G.F. (1973) - Catalogo sistematico ragionato della fauna cavernicola della Sardegna. Rendiconti Seminario Facoltà Scienze Università di Cagliari 43(3-4), pp. 151-205.
Sanna N., Puddu S., Bartolo G. (1972) - Su Mannau. Editrice Sarda Fossataro Cagliari, 115 p.
Sanna U. (1996) - Grotta di Su Mannau. Il punto sulle nuove scoperte. Sardegna Speleologica 9, pp. 3-11.

ond, and provide large part of the population in drinking water. Another karst spring of great historical interest is Caput Acquas (80 l/s), near Villamassargia, captured by the Roman acqueduct of Cagliari of which remain little traces. This spring probably attains the water from the distant Marganai carbonatic complex, as has been suggested by geophysical surveys (Atzeni et al., 1992). The last karstspring is the Gran Sorgente, that has been intercepted by an artificial gallery of the San Giovanni mine at the end of last century, giving an initial flow rate of 3500 l/s, stabilising after half a year at 1400 l/s (Civita et al., 1983).

Among the abundant mineralisations all over Iglesiente and Sulcis area, some deposits are characterised by their karstic genesis (paleokarst). The four most interesting examples are Campi Elisi, Mount San Giovanni, Mount Barega-Mount Arcau-Sa Bagattu chain and Is Arenas. At Campi Elisi mining activity has literally emptied paleokarst mineralisation, revealing the original cave boundaries. The same phenomena are present on top of Mount San Giovanni and on the carbonatic chain that develops from Mount Barega to Mount Sa Bagattu, where ancient excavations have exploited paleokarst pockets for both argentiferous lead-zinc and barite fillings. Karst is very well developed in these three areas, and mining galleries have intercepted lots of natural cavities filled with mineralisations of all kinds. The last paleokarst described is the Is Arenas mining crater, an enormous open pit excavation that exploited until recently a mineralised horizon covered by a siliceous

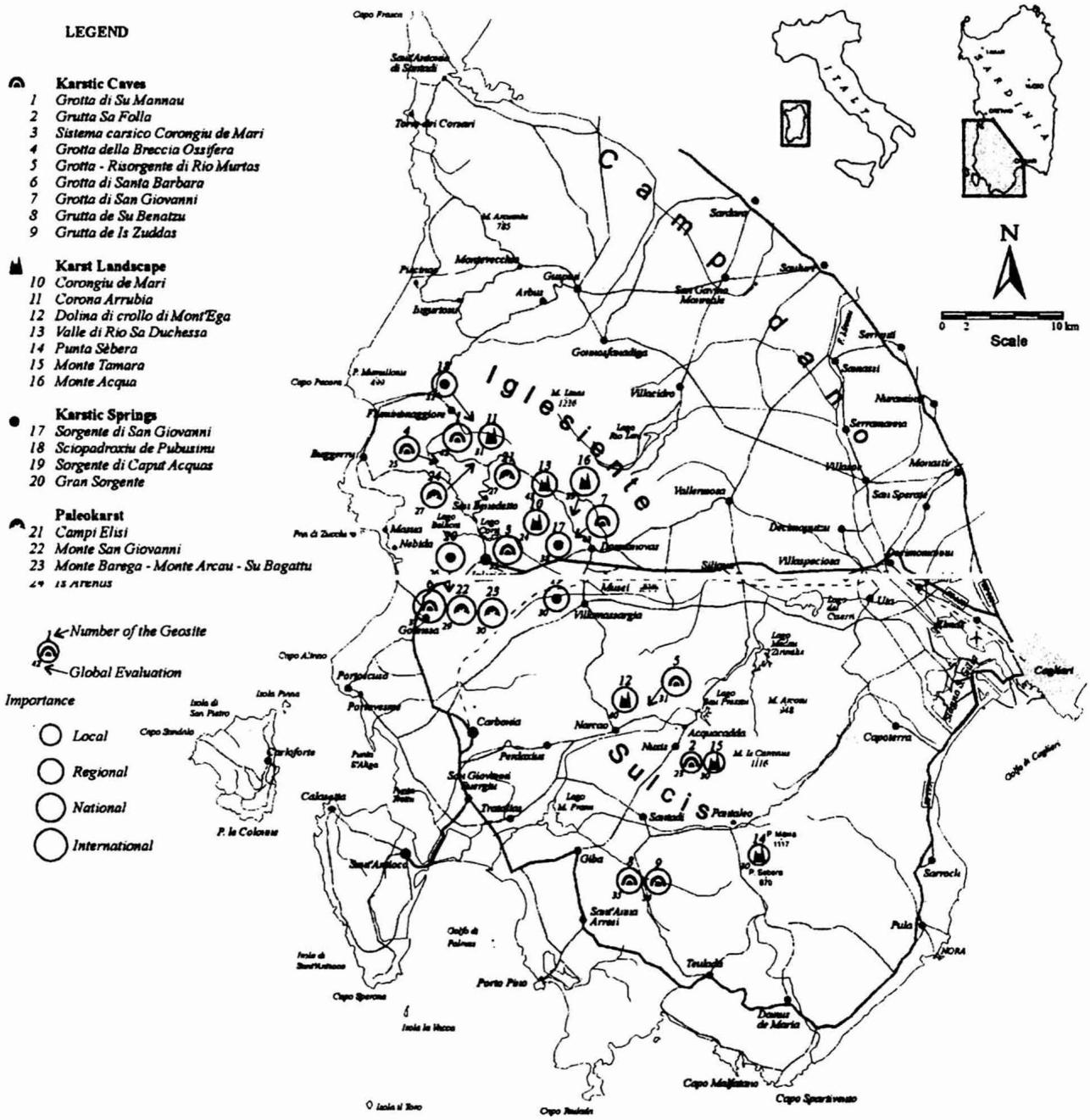


Fig. 3. Map of Sulcis-Iglesiente area with the karstic geosites and their global value.

caprock. This deposit has been interpreted as a paleokarst deposit, that filled sinkholes and cavities in ceroid limestones, covered afterwards by Ordovician conglomerates.

Besides these most representative karstic geosites chosen for this work, many others can be mentioned: the Paradiso cave near Fluminimaggiore, the so-called "grotta del Cancello" at Iglesias, the Nebida coast with the great Pan di Zucchero monolith, and the karstic canyon of Gutturu Cardaxius that cuts the calcareous rocks for several chilometers to end at sea in the beautiful Cala Domestica beach.

Conclusions

Table 1 reassumes the main characteristics of the twenty-four geosites described above, their position, their evaluation and their importance on a geographic scale. These data have been visualised in a map of the geosites (Fig. 3), showing the high density of important karst phenomena in the Iglesiente-Sulcis area. Of all geosites described, 2 are of international, 9 of national, 10 of regional and the remaining 3 of local interest. Especially the two international sites, the San Giovanni and the Santa Barbara caves,

Table 1
List of the karst geosites of the Cambrian Sulcis-Iglesiente Area

Geosite's name	Genetic definition	County	Qualifying elements*	Global value	Importance
1 Su Mannau show cave	Karstic Cave	Fluminimaggiore	w, b, s, d, t	42	National
2 Sa Folla cave	Karstic Cave	Nuxis	a	23	Local
3 Corongiu de Mari karst complex	Karstic Cave	Iglesias	d, w, s, a	33	National
4 Breccia Ossifera cave	Karstic Cave	Fluminimaggiore	s	25	Regional
5 Rio Murtas resurgence	Karstic Cave	Narcao	s	31	National
6 Santa Barbara cave	Karstic Cave	Iglesias	b, s, m	37	International
7 San Giovanni cave	Karstic Cave	Domusnovas	b, w, d, a, s, t	43	International
8 Su Benatzu cave	Karstic Cave	Santadi	a	35	Regional
9 Is Zuddas show cave	Karstic Cave	Santadi	b, t, s	34	National
10 Corongiu de Mari hills	Karst landscape	Iglesias	a, p	24	Regional
11 Corona Arrubia Massif	Karst landscape	Fluminimaggiore	p	31	Regional
12 Collapse Doline of Mt. Ega	Karst landscape	Narcao	b, p	40	Regional
13 Valley of Rio Sa Duchessa	Karst landscape	Domusnovas	b, m	43	Regional
14 Mt. Sèbera	Karst landscape	Domus de Maria-Teulada	p	30	Local
15 Mt. Tamara	Karst landscape	Nuxis	p, m	30	Local
16 Mt. Acqua	Karst landscape	Domusnovas	p, s	39	National
17 San Giovanni spring	Karstic springs	Domusnovas	w, d, s, p	38	Regional
18 Pubusinu spring	Karstic springs	Fluminimaggiore	w, d	32	Regional
19 Caput Acquas spring	Karstic springs	Villamassargia	w, a	30	Regional
20 Gran Sorgente	Karstic springs	Iglesias	w, m, d	26	National
21 Mineralisation of Campi Elisi	Paleokarst	Iglesias	p, m	27	Regional
22 Mt. San Giovanni	Paleokarst	Gonnesa-Iglesias	p, m, s, a	29	National
23 Mt. Barega-Mt. Arcau-Sa Bagattu	Paleokarst	Iglesias	p, m, s	30	National
24 Mineralisation of Is Arenas	Paleokarst	Iglesias	d, s, p, m	30	National

* b=scenic, w=presence of drinking water, s=scientific interest (genetic, palaeontologic, mineralogic, biologic), d= dimension, a= archeology, p=panorama, t= touristic, m=mining archaeology

should be interested by a program of sustainable tourist development, as has been suggested in several occasions. This study hopefully can contribute to increase the knowledge of these peculiar characteristics, in order to arrive at their valorisation and protection in the very near future, perhaps in the "geomining Park of Sardinia" recently proposed and recognised by Unesco.

Acknowledgement. Research realised with the contribution of the "Ministero dell'Universita e della Ricerca Scientifica (MURST 60%), in the Project "Monumenti Geologici e Geomorfologici", Coordinator Prof. Felice Di Gregorio and of the Eoropean Community, PO94/99.

References

Alba, L., De Waele, J., Grafitti, G., Pisano, M., Spiga, R. 1996. Le grotto r il carsismo di Corongiu de Mari (Iglesias, Sardegna sud occidentale). Monografia di Antheo 5; 88p.

Atzeni, W., Balia, R., Bianco, L., Deidda, G. P., De Weale, J., Vernier, A. 1994. Prime ipotesi sulla continuita idrogeologica tra il massiccio del Monte Marganai e gli affioiramenti carbonatici della Piana del Cixerri. - *Atti del 20 Convegno Nazionale dei Giovani Ricercatori di Geologia Applicata,* Viterbo 1992, *Geologica Romana* 30; 239-244.

Barca, S., Di Gregorio, F. 1991. Conservation et valorisation du patrimoine geologique de la Sardaigne (Italy): une proposition metodologique. - *1er Symposium International "Protection du Patrimoine geologique"*, Digne le Bains, France.

Bechstadt, T., Boni, M. 1996. Sedimentological, stratigraphical and ore deposit guide of the autochtonous Cambro-Ordovician of Southwestern Sardinia: some conclusive remarks. - *Risoconti dell'Associazione Mineraria Sarda* 87(1); 91-115.

Boni, M. 1982 Paleokarstic ores in SW Sardinia: some conclusive remarks. - *Resoconti dell'Associazione Mineraria Sarda,* 87(1); 91-115.

Chessa, L., de Waele J., Trogu, A. 1994. Il sistema carsico di Corongiu de Mari (Iglesias, Sardegna sud occidentale). - *Atti del XVII Congresso Nazionale di Speologica,* Castelnueva Garfagna 1994; 147-153.

Civita, M., Cocozza, T., Forti, P., Perna, G., Turi, B. 1983. Idrogeologica del bacinominerarion dell'Iglesiente (Sardegna sud occidentale). - *Memorie dell'Istituto Italiano di Spelèologica* II(2), 137p.

Corona, O., Serri, R., Villani, M. 1983. La voragine Is Seddas. - *Speleologica Sarda* 45; 13-19.

Curreli, R., Di Gregorio, F., Floris, A. 1992. Evoluzione naturale e impatto antropico nel Sistema carsico di Is Zuddas (Sardegna SW). - *Bolletino della Associazone Italiana di Cartografia* 86; 60-69.

Forti, P., Perna, G. 1981. La turisticizzazione della Grotta Santa Barbara nella Miniera Di San Giovanni e la creazione di un Museo Minerario ad essa conneso (Iglesias-sardegna sud occidentale). - *Le Grotte d'Italia* 4(10); 181-187.

Forti, P., Perna, G. 1982. Inventario delle cavita dell'Iglesiente. In Le Cavita naturali dell'Iglesiente. - *Memorie dell'Instituto Italiano di Speleologica,* Serie II, v. 1; 55-229.

Padalino, G., Pretti, S., Tamburrini, D., Tocco, S., Uras, I., Violo, M., Zuffardi, P. 1972. Carsismi e mineralizzazioni. - *Rend. della Società Italiana di Mineralogia e Petrologia,* 28; 215-230.

Ulzega, A. 1968. Grotta con breccia ossifera nella Valle del Rio Antas (Iglesiente). - *Bolletino Societa Sarda Scienze Naturali* 2(2); 1-8.

Ulzega, A. 1968. Osservazioni geomorfologiche, con particolare riguardo al carsismo, sul settore cambrico del Monte Conca s'Omu (Iglesiente, Sardegna sud-occidentale). - *Rendiconti Seminario Facoltà di Scienze dell'Università di Cagliari,* 47(3); 631-642.