GIS-based landscape analysis of megalithic graves in the Island of Sardinia (Italy)

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Abstract:

One of the most important megalithic groups in Western Europe in terms of number and characteristics is the group of over 200 monuments of various types in Sardinia. It now seems to be confirmed that the rise of the megalithic phenomenon was during the culture of San Michele of Ozieri (Late Neolithic, 4000-3300 B.C.E.). The Sardinian dolmen graves, however, had a maximum distribution during the Chalcolithic, as evidenced by most of the finds from excavations. The phenomenon also shows a close relationship beyond Sardinia and especially with the monuments of Catalonia, Pyrenees, non-coastal departments of French-midi, Corsica and Puglia.

About 90 dolmen graves of various types have been investigated, namely the simple type, "corridor" type, "*allée couverte*" type, and others of uncertain attribution, located in central-western Sardinia, and particularly in a significant area of ca. 3500 km^2 coinciding with the historical regions of Marghine-Planargia, Middle Valley of Tirso and Montiferru. This includes some 40% of all Sardinian dolmens. Locational trends and relationships with regard to landscape elements were studied with the aid of GIS methodologies such as viewshed and cost surface analysis. This allowed an evaluation of the role of visual dominance on the surroundings in relation to waterways and natural access routes.

These dolmens enjoy an isolated positional character, being found more often in high plateaus, but also on low plateaus and hills. Although different concentrations are found in dolmenic graves, these do not seem to have any direct relationship among them, but their influence is apparently directed towards travel routes and sensitive elements of the landscape that have capabilities of territorial demarcation.

The particular location emphasizes the significance of these monuments as territorial markers for segmentary societies. It seems that a dolmen was constructed according to the territory immediately surrounding it. This reinforces the hypothesis of there being a secondary task, in addition to that of burial, to symbolize a message or landmark for those who moved towards "another" territory: a sign of belonging.

Keywords: dolmen; GIS; landscape; Neolithic; Sardinia

Sommario:

Uno dei più importanti gruppi megalitici dell'Europa occidentale in termini di numero e caratteristiche è quello presente in Sardegna, che consta di oltre 200 dolmens. Sembra essere

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confermato che la genesi del fenomeno sia avvenuta durante la cultura di San Michele di Ozieri (Tardo Neolitico: 4000-3300 B.C.E.). I dolmen sardi, però, hanno avuto la loro massima diffusione durante il Calcolitico, come evidenziato dalla maggior parte dei reperti provenienti dagli scavi. Il fenomeno dolmenico sardo mostra anche strette relazioni con aree extra-insulari, soprattutto con i dolmens della Catalogna, dei Pirenei, con quelli delle province non-costiere del sud della Francia continentale, con la Corsica e la Puglia, nell'Italia meridionale.

Sono stati analizzati in questa sede circa 90 dolmens di varie tipologie: di tipo semplice, a "corridoio", ad '*allée couverte*' e altri di attribuzione incerta, situati nella Sardegna centro-occidentale, e in particolare in una zona significativa di circa 3500 km^2, coincidente con le regioni storiche del Marghine-Planargia, della Media Valle del Tirso e del Montiferru. Il campione indagato comprende così il 40% circa di tutti i dolmens sardi. Sono state studiate le tendenze ubicazionali e le relazioni con gli elementi del paesaggio con l'ausilio di metodologie GIS come la viewshed analysis e la least-cost path analysis.

I dolmens analizzati si trovano più spesso presso altipiani, ma anche su colline basse. Sono prevalentemente isolati, ma in rari casi sono raggruppati in necropoli. Sebbene in alcune aree siano stati individuati dei raggruppamenti di questi monumenti, essi non sembrano però avere rapporto diretto tra loro, ma la loro ubicazione è probabilmente legata a vie di percorrenza e ad elementi sensibili del paesaggio, così da suggerire un ruolo di marker territoriale.

La particolare posizione sottolinea il ruolo di questi monumenti come marcatori territoriali per società segmentarie. Sembra che i dolmens siano stati edificati in relazione col territorio immediatamente circostante. Questo dato rafforza l'ipotesi che i dolmens, oltre che la funzione primaria di sepoltura, svolgessero anche un compito secondario, con l'obbiettivo di simboleggiare un messaggio o rappresentare un punto di riferimento per coloro che avevano la necessità di muoversi verso territori pertinenti a diversi gruppi umani: un segno di appartenenza.

Parole chiave: dolmen; sistema informativo territoriale; archeologia del paesaggio; Neolitico; Sardegna

1. Introduction

In Sardinia archaeologists have shown an important megalithic phenomenon, consisting of over 200 dolmens, situated for the most part in the central-northern area of the island. Currently, we know of at least 221 dolmen monuments. As regards typology, the dolmens belong to five main categories: simple type, "corridor" type, "side entrance" type, "mixed" type (i.e. monuments partly excavated in the rock and partly built with orthostats and dolmenic coverage) and '*allées couvertes*'. The majority of the dolmenic burials belong to the simple class, followed by the *allées couvertes*, while only few tombs are of other kinds.

From the point of view of chronology, there are no radiocarbon dates. The data from recent stratigraphical investigations, the archaeological materials sporadically recovered in some dolmens, the structural and cultural relationships among the Sardinian dolmens and other prehistoric monuments of the island, typological comparisons with similar dolmenic monuments of various extra-insular areas, allow however to report that the dolmens of Sardinia belong to a time period ranging from the late Neolithic to the Eneolithic (from the end of the fourth to the beginning of the second millennium B.C.E.), perhaps with a degree of reuse in the Bronze age.

Recent research has highlighted tight structural and cultural relationships between the megalithic monuments of Sardinia with some extra-insular regions, as in Iberia, France and especially Corsica.

In the present work we want to analyze systematically the relationship among the megalithic graves and the surrounding environment. We believe that the lithology and especially the geomorphology are extremely important factors in order to better understand the dolmen phenomenon and the locational modalities of these burial structures.

To achieve the proposed objective, it was decided to study the dolmens present in a sample area of west-central Sardinia, characterized by a high concentration and, regarding the geomorphological aspect, especially by a plateau environment, that constitutes the preferred morphological landscape for the building of dolmens across the whole island (Figure 1).

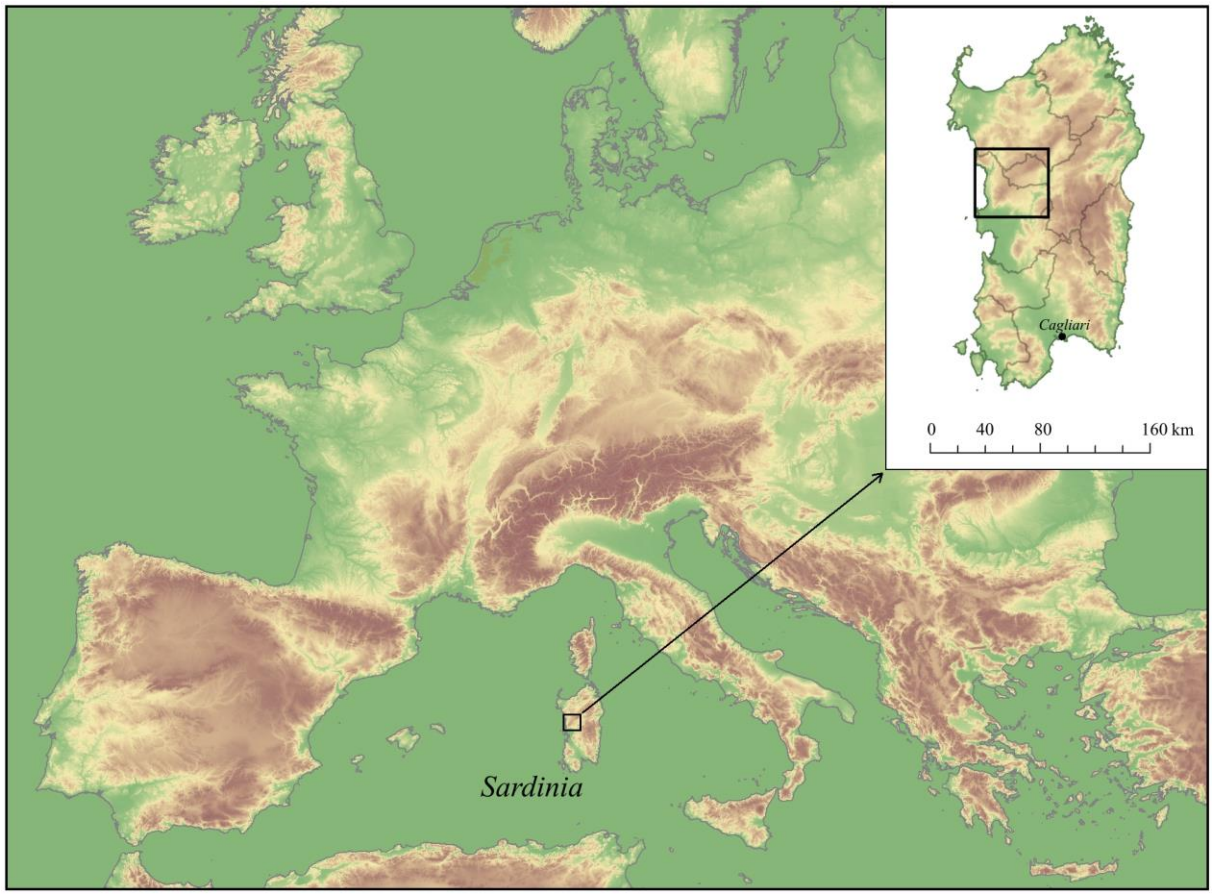

Figure 1. Sardinia and the study area (Elaboration of the Authors on the basis of a raster map of the European Environment Agency).

1.1. The territory

The geographical zone under consideration includes an area of about 1790 km^2; it consists of three areas characterized by geomorphological forms typical of the plateau, known as the highlands of Abbasanta, Campeda and Planargia (Figure 2), and two mountain ranges, Montiferru and Marghine, that form an arc from southwest to northeast. The largest area is the basaltic plateau of Abbasanta, whose surface is slightly inclined from north-west to south-east: it is not very rugged, the valleys are few and hardly visible, and average altitude varies from 300 to 400 m. a.s.l. (Mori 1975).

The formation of the plateau took place during the Middle-Upper Pliocene, when in Sardinia the tectonic graben of the Campidano began to descend and volcanic activity awoke, particularly in the Monte Arci and in Montiferru: the copious basaltic emissions gave rise to the vast basaltic plateaus characteristic of the central and northern parts of the island. It was the same origin for the Campeda plateau which extends to the north of Abbasanta plateau. It is separated from the Marghine near the mountain formations included in today's territories of Lei, Silanus, Bolotana, Bortigali and Macomer. At the western border of Campeda there is the Planargia region which, as the name suggests, indicates a small zone mainly flat and set on two levels: the upper one (average altitude 340m) is a basaltic plateau, the lower one with

hillside peculiarity slopes down to the mouth of the river Temo and the region of Villanova, which marks the north-west border.

Figure 2. Dolmen Terra Tenera-Macomer. In the background is the plateau of Campeda (photo by R. Cicilloni).

The Planargia is limited to the west by the sea and to the south by the Riu Mannu that separates it from the Montiferru. In the north-east the area is bordered by the Marghine. Finally mountainous areas delineate the areas of plateau. The Montiferru is the largest of the ancient Sardinian volcanic systems, consisting of a set of trachytic and basaltic rocks that extend for about 700 km^2, reaching the highest elevation with Monte Urtigu (1050 m a.s.l.).

The whole is a complex that appears like a big flattened cone with simple and regular shapes but strongly affected by valleys that descend from all sides except the north-east, where the mountain connects with Marghine and Campeda. The central backbone of the massif is composed of trachytic lavas, while the sides of higher slope comprise basaltic flows younger than the central lavas. The basalts that expanded on the sides of this ancient volcano constitute today a large crown of plateaus that characterizes the environment of our study. As just mentioned, in the north-east of Montiferru there is the Marghine massif characterized to the south by steep slopes and much more rugged shapes. In another way we can say that the two environments are closely related: in fact the Marghine constitutes the hem of Campeda, which further east, towards the Tirso valley, occurs with steep forms and imposing fronts at the territory of Bortigali. Among the highest peaks of Marghine are Monte Santu Padre (1030 m), Punta Iammeddari (1118 m), and the highest peak Punta Palai (1200 m above sea level). The Campeda plateau instead has an average altitude of 650 meters.

1.2. Previous research

The presence of megalithic graves in Sardinia was known since the beginning of last century. The first scientific work that concerns a Sardinian dolmen was, the article published by the archaeologist Taramelli (1906), who reported the existence of the dolmen Sa Perda 'e

S'Altare in the territory of Macomer, the first monument of this type discovered in Sardinia. Subsequently, Taramelli (1916; 1919) and other scholars took up the argument, among them Mackenzie (1910; 1913), Davies (1939), Lilliu (1968; 1988), Atzeni (1968; 1982; 1988), Santoni (1973), and Moravetti (1998a). Finally, there is a book by Cicilloni (2009) about all known Sardinian dolmens.

However, none of the cited studies treated specifically the relationship between dolmens and the landscape. They merely note that the morphological environment in which these burial buildings most often rise is the plateau, followed by low tablelands and hilly areas (Cicilloni 2009: 136), with all environments linked in the past and the present to a pastoral economy (Lilliu 1988: 197).

As regards the area under examination, besides information provided by the researchers mentioned above, there are only signalings of single dolmenic monuments: for example, in the works on the historic regions of Marghine and Planargia (Moravetti 1998b; 2000) and on the areas of Cuglieri (Pes 2009), Sedilo and Aidomaggiore (Tanda 1996; 1997; 1998), Abbasanta and Norbello (Cicilloni 1997; Usai 1999), Narbolia (Usai 2005), Neoneli (Loi 2012), and Bonarcado-Seneghe (Maisola 2012).

However, there are no studies and reflections on the dolmen megalithism of the area in general, except for the observation of some authors on specific zones of the sample area: for example the analysis of Moravetti (2000: 36-38) on Marghine-Planargia and the accurate exposure of Paschina (2000: 428-434) on the dolmen phenomenon in the territory of Macomer.

In Sardinia no GIS-based territorial analysis has ever been done regarding the dolmens. The GIS methodology for the study of the archaeological landscape has been applied till now only on sites and monuments of protohistoric age (see for example, Puggioni 2009; Angius *et al.* 2010, 2012; de Montis & Caschili 2012; Fenu *et al.* 2012; Sanna 2012; Vanzetti *et al.* 2013; Cicilloni & Cabras 2014).

1.3. Dolmen graves in the sample area

In the examined area there are 90 megalithic tombs. The largest concentration (71% of total) is localized at the plateaus of Abbasanta (64%) and Campeda in the North of Macomer (7%). (Figure 3).

This area of concentration, located in the South of the Marghine, sees the presence of the vast majority of the monuments subjected to this analysis. The other areas of concentration of dolmens, again in a plateau environment, are those of Suni and Sindia (12%), lowland areas in the countryside of Cuglieri sloping down to the high sea coasts between Torre Foghe (mouth of the Riu Mannu) to the north and Santa Caterina di Pittinurri (mouth of Riu Santa Caterina) to the south, and the foothills of Montiferru near Narbolia (3%). Their locations in rugged areas have lower rates (14% of the monuments). 83% then are located in plateau, some crowning the edges and corners with a large view of the land below or the canyons that penetrate these volcanic formations. Others, such as the dolmen Baccarzos of Noragugume, are located at lower altitudes, at entrances to canyons that from lower territories rise to the top of the highlands. However, most of the analyzed dolmens are located at the centre of the highlands, away from these positions listed above with a scattered distribution across the territory which tends to his massive occupation.

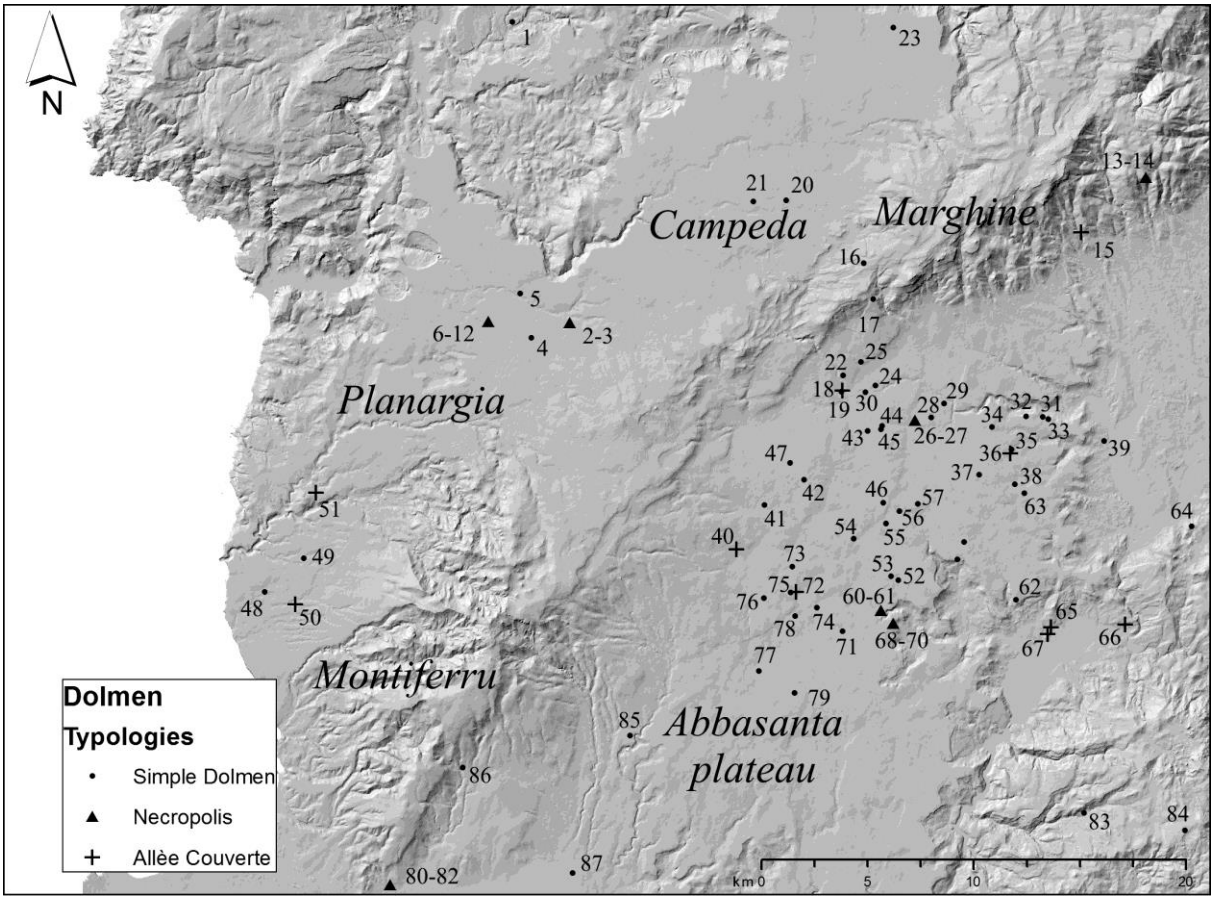

Figure 3. Map of distribution of the examined dolmens: 1. San Sebastiano-Padria; 2. Nela I-Sindia; 3. Nela II-Sindia; 4. Serrese-Sindia; 5. Furrighesu-Sindia; 6. Matta Larentu I-Suni; 7. Matta Larentu II-Suni; 8. Matta Larentu III-Suni; 9. Matta Larentu IV-Suni; 10. Matta Larentu V-Suni; 11. Matta Larentu VI-Suni; 12. Matta Larentu VII-Suni; 13. Tanca Noa A-Bolotana; 14. Tanca Noa B-Bolotana; 15. S. Basilio-Lei; 16. Tuide-Bortigali; 17. Carrarzu Iddia-Bortigali; 18. Sa Perda 'e S'Altare-Macomer; 19. Tanca Sa Marchesa-Macomer; 20. Su Edrosu-Macomer; 21. Terra Tenera-Macomer; 22. Bidui-Macomer; 23. Aeddo-Macomer; 24. Sa Tanca Sar Bogadas-Birori; 25. Noazza-Birori; 26. Arbu I-Birori; 27. Arbu II-Birori; 28. Corrizzola-Birori; 29. Mura Pranosa-Birori; 30. Pradu Lassia-Birori; 31. Sa Fronte Uda-Dualchi; 32. Mazzarighe A-Dualchi; 33. Mazzarighe B-Dualchi; 34. Lughe-Dualchi; 35. Badde Ide-Dualchi; 36. Brancatzu-Dualchi; 37. Paule Rues-Dualchi; 38. Baratta-Dualchi; 39. Baccarzos-Noragugume; 40. Pedra in Cuccuru-Borore; 41. Giuanne Pedraghe-Borore; 42. Muttianu-Borore; 43. Sa Matta e sa Ide-Borore; 44. Serbine A-Borore; 45. Serbine B-Borore; 46. Arghentu-Borore; 47. Su Narbanu-Borore; 48. Monte Lacana-Cuglieri; 49. Su Livrandu-Cuglieri; 50. Su Lizu-Cuglieri; 51. Sa Cobelcada-Sennariolo; 52. Succhiau-Aidomaggiore; 53. Mura Fratta-Aidomaggiore; 54. Tuvamene-Aidomaggiore; 55. Nucrastala-Aidomaggiore; 56. Meddaris-Aidomaggiore; 57. Su Nuradorzu-Aidomaggiore; 58. Scarallotza-Aidomaggiore; 59. Crobecada-Aidomaggiore; 60. S'Aspru I-Aidomaggiore; 61. S'Aspru II-Aidomaggiore; 62. Iloi-Sedilo; 63. Lure-Sedilo; 64. Filigorri-Sedilo; 65. Monte Trigu-Sedilo; 66. Torozzula-Sedilo; 67. Monte Paza-Sedilo; 68. Nurarchei A-Norbello; 69. Nurarchei B-Norbello; 70. Nurarchei C-Norbello; 71. Abbamuru-Norbello; 72. Sa Perda Piccada-Norbello; 73. Sa Codina 'e S'Ispreddosu-Norbello; 74. Mura 'e Iscovas-Norbello; 75. S'Angrone-Abbasanta; 76. Mesu Enas-Abbasanta; 77. Cannigheddu 'e S'Ena-Abbasanta; 78. Mura 'e Putzu-Abbasanta; 79. Su Nuratzolu-Abbasanta; 80. Carrazzu I-Narbolia; 81. Carrazzu II-Narbolia; 82. Carrazzu III-Narbolia; 83. S. Maria di Olisai-Neoneli; 84. Nole-Neoneli; 85. Serra Crastula-Bonarcado; 86. Serra Passa-Seneghe; 87. Su Conzau de Is Froris Grogus-Milis (Elaboration of the Authors).

We note that these dolmens are rarely grouped in necropoli (except for Matta Larentu-Suni, with at least seven, Nurarchei–Norbello and Carrazzu-Narbolia, with three dolmens), but are usually located in isolated places or, when there are several in the same area, at a good distance from each other, almost as if delimiting in some way a piece of territory.

The megalithic tombs of this area are mostly simple dolmens (71%) (Figure 4), but also *allées couvertes* (15%) (Figure 5). Among the simple dolmens, their plans are mainly quadrangular (68%), but also circular (32%). So are of uncertain typological attribution.

Figure 4. Dolmen Matta Larentu I, Suni (simple type) (photo by R. Cicilloni).

The building material most often used is basalt (73%), being locally the more diffused type of rock having regard to the geological structure of the area. Also used was trachyte, granite and limestone.

The orientation of the entrances of the dolmens is interesting (Hoskin 2001). In Sardinia we know the orientation of only 52 dolmens (60% of the total). We cannot determine the orientation of the others because they are destroyed or undetectable. There are orientations toward all the points of the compass, but 52% of those considered are oriented towards south-east, 13% to east, 11% to south-west and 8% to south, while other directions have lower percentages. These data can be compared with those of the other dolmen tombs of Sardinia, where most of them are orientated to south-east (41%) (Cicilloni 2009: 151-153). However, this preference is often found in the dolmen monuments of Western Europe: *i.e.* orientation towards the arc that goes from east to south in dolmens of the Atlantic coasts, from Brittany to the Basque country (Chevalier 1984), in Catalonia (Esteva Cruañas 1970), in some departments of central-southern France (Chevalier 1984) and in Corsica (Cesari 2001). We cannot determine with certainty the reasons for the orientation of the dolmens, but we believe that it is probably connected to magical-sacral motives, so the builders of these monuments chose an orientation related to certain points of the horizon, for example, where the sun rises or sets at certain times of the year (Cicilloni 2009: 152).

Figure 5. *Allée couverte* Pedra in Cuccuru, Borore (photo by R. Cicilloni).

The dolmens of Serrese-Sindia and Monte-Paza Sedilo, which are decorated on the upper surface of the coverage slab, stand out in importance.

In the first monument, on the upper surface and on the edges of the slab there are narrow incisions which form, on each of the sides, except the entrance, some figures. Two of them, on the north and west sides, might be anthropomorphic. The figure on the south side is a rectangle, divided into four parts, connected to the figure of the west side. On the south-west and north-east corners there are engraved irregular semicircles. The engravings extend also across the thickness of the slab, and they are cut by a further line which, along the thickness, runs horizontally all around the table (Figure 6).

There are no precise comparisons with other examples of megalithic art in Western Europe, but only very general similarities with "U" motifs and crossed lines engraved on orthostats of French and English dolmens (Shee Twohig 1981).

Engravings are also present on a trachytic slab found in Monte-Paza Sedilo, presumably pertinent to a passage tomb. There is a schematic decoration with shells, concentric circles with a single radial line, and a schematic anthropomorphic female figure (Melis 1996) (Figure 7).

The motifs of concentric circles with a single radial line have close comparisons with the engravings present on some standing stones of the territory of Mamoiada, and in particular on the monumental Stele of Boeli (Fadda 1997; Atzeni 1998; Manca & Zirottu 1999). Outside of Sardinia, these figurative motifs are found in megalithic monuments of the Irish, for example in the megalithic necropolis of Loughcrew (Co. Meath) (Shee Twohig 1981: 202-220) and on the monumental standing stone of Ardmore (Co. Donegal) (McNally 2006: 98).

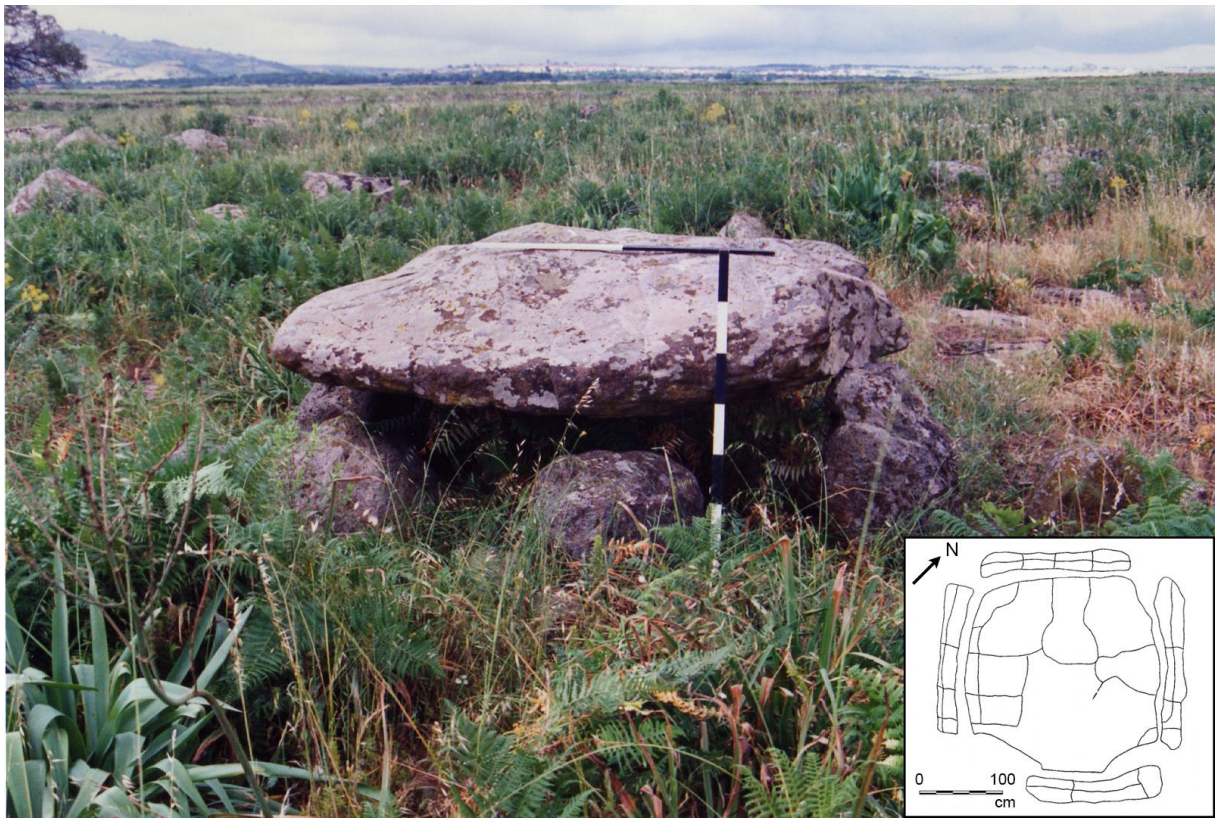

Figure 6. Dolmen Serrese, Sindia (simple type), with petroglyphs on the coverage slab (photo by R. Cicilloni).

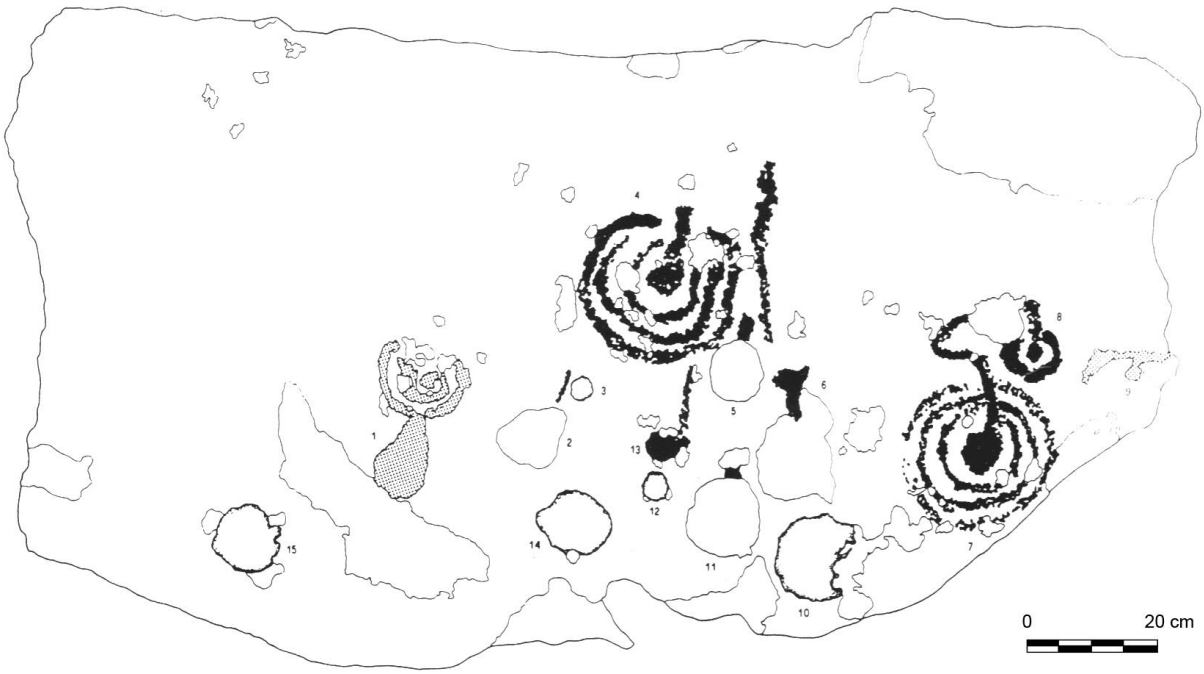

Figure 7. Megalithic monument of Monte Paza-Sedilo (*allée couverte* type), with petroglyphs on a slab (adapted by Melis 1996).

2. Methods

2.1. Objectives

In recent years, the analysis of settlement characteristics of dolmen burials led to an interpretation of this major monumental display - so well diffused across much of Europe - being approached as having the role of territorial marker (Chapman 1981; Jarman *et al.* 1982; Renfrew 1983; Criado Boado 1989; Patton 1992; Barnatt 1998; Thomas 1998; Parker Pearson 1999; Cámara Serrano 2001; Depalmas 2001; Scarre 2007; García Sanjuán 2011). The dolmen assumed a certain symbolic value for those who were to walk the areas in their vicinity and could be compared to the role of contemporary menhirs (Lilliu 1988: 87; Soula 2012: 579) that in many cases are located in proximity of dolmens (Cicilloni 2009: 164-165).

In Sardinia, menhirs associated with dolmens were found at S. Lorenzo, Mesu Serra I, Berre, S. Stefano, Monte Cuccu I-II, Malghesi, Arcone, Montiju Coronas, Oronitta, Monte Sa Rughe I, Monte Mannu, S. Lisei, Sa Pirichedda I, II e III, S. Basilio, Lussurgiu, Sa 'Onca 'e sa 'emina, Minde Puzzu, Sa Corte Noa e San Basilio (Cicilloni 2009: 164-165). The dolmen burials should have a "monumental" connotation as testified by the presence of peristaliths, whose remains are often observed around the central core of the dolmens (Giot 1976: 204-205; Cesari 2001: 12; Cicilloni 2009: 21, 150-151). The peristalith is found in the dolmens of Mesu Serra I, Doli Fichima II, Sa Janna de su Laccu, Elcomis, Pubusattile, Su Coveccu, Tespile, Su Urreddu, Nela I, Matta Larentu, Matta Larentu III, Matta Larentu IV, Matta Larentu V, Matta Larentu VI, Tanca Noa A, S. Basilio, Sinne, Motorra, Cucchè-Zia Arvara, Tuide, Sa Perda 'e S'Altare, Tanca Sa Marchesa, Su Edrosu, Terra Tenera, Bidui, Sa Tanca Sar Bogadas, Noazza, Arbu I, Arbu II, Corrizzola, Pradu Lassia, Sculacacca, Sa 'Onca 'e sa 'emina, Badde Ide, Paule Rues, Giuanne Pedraghe, Sa Matta Ide, Serbine A, Arghentu, Monte Lacana, Su Lizu, Sa Cobelcada, Nucrastala, Meddaris, Su Nuradorzu, Scarallotza, Iloi, Lure, Filigorri, Perda Longa, Carazzu, and Sa Corte Noa (Cicilloni 2009: 150-151).

We are in presence of a form of worship linked to the land because there was a contact with it, as also demonstrated by contemporary *Domus de Janas* (Tanda 2009: 67). Also, the building characteristics of the dolmens reflect undoubtedly the willingness to appear and to visually communicate, that combine well with locational conditions of good visual domain on the surrounding landscape, at the edges of plateaus or in their vicinity, near steep slopes that overlook areas of lower elevation. As regards the nature of these events, some researchers have suggested that they could be related to paths of transhumance (Tanda 2009: 68), within a contrast pattern, traditionally prevalent in the archaeological Sardinian literature, among farming communities, whose funerary aspect manifested itself in the so-called *Domus de Janas* caves, and pastoral communities, who buried in dolmens (Lilliu 1988: 197).

Without tackling in detail the complex issue of transhumance in Sardinia this aspect can be outlined, at least for Sardinia, in its general features. It is usual, unfortunately, that there is no direct evidence for the final phases of the Late Neolithic and the Copper Age - the chronological range in which are dated the Sardinian dolmens (Cicilloni 2009: 182-183). It is important, however, to clarify the issue.

The territorial object of our analysis is not an area normally affected by historical long-range transhumances known and documented in Sardinia from the Middle Age onwards: those who moved from the areas of Gennargentu, Barbagia, Mandrolisai and Ogliastra towards the regions of Campidano and Sulcis-Iglesiente, Gerrei and Sarrabus, Baronia, Nurra (Ortu 1988: 821), with distances covered between 30-60 and 50-120km, probably by retracing earlier roads. It must be noted that transhumance, in traditionally known continental manifestations, involves moving livestock during hot weather to areas more suitable, in terms of climate, for grazing. The Sardinian phenomenon had though, historically, its opposites in direction and timing. In the island there is a spatial and seasonal different approach by the

pastor to transhumance, with the aim of spending the cold season, instead of the summer, in places with a warmer climate (Ortu 1988: 822).

In this regard, although it is not possible to treat in detail every local circumstance, literary sources mention the *mudas* phenomenon, a transhumance of small scale limited to the municipalities or micro-regions of Sardinia (Ortu 1988: 822-823). Transhumance of least distance ("*practica de trasterminancia*") has been suggested, on the basis of the growing number of farm animals encountered in the archaeological record, for the Copper Age in Seville (Andalucía – Spain) (Murrieta Flores *et al.* 2011: 214). As Ortu (1988: 824) says, transhumance is "a passage of borders", and it is here that we find the links to some parts of our investigation, with the aspect of boundary marker and at the same time of communication of a message to the outside already advanced by other scholars for several areas of the island (Spanedda & Cámara 2009: 155), relating to a membership of a group to a territorial entity manifested through megalithic tombs (Afonso Marrero *et al*. 2010; Spanedda 2010). The claim: "If this step is not legitimate, authorized or agreed, it becomes a 'trespassing' and it is a source of conflict" (Ortu 1988: 823), referred to transhumance, might suggest a vision of the landscape as a palimpsest in which also the people of Sardinian prehistory were closely related with alternate issues of ownership and territorial relationships. Contact areas between groups/people or zones of strategic interest were probably enshrined in monumental form, with single monuments or even as necropoli, witnessed for example at Matta Larentu-Suni (Moravetti 2000: 320-324), Caratzu-Narbolia (Maisola 2012: 53-55) or in an external case to our study area at Su Sordanu-Nughedu San Nicolò (Basoli 1998: 151; Basoli 2001: 107).

It is clear that this parallelism leads us to compare phenomena very distant in time, and it is also clear that the lack of comprehensive stratigraphic data makes more difficult the reconstruction of archaeological context. However, the area of central-western Sardinia - the object of our analysis - offers us a large monumental sample that includes about 40% of the islanders finds. Having noticed the typical locational choice of the dolmenic burials, we tried to investigate the characters that may have affected movement in these territories. We have tried, thus, to simulate a series of paths that, through the ages, have been able to have a relationship with the dolmens.

At a time when a shepherd designs and reasons about hypothetical shifts functional to relationships that he engages with the territory and its resources, the mobility through the space around it is based and structured according to a set of routes that probably, if they were in direct connection with the activities of subsistence, tended to avoid the most inaccessible areas or difficult journeys, thus making a selection between difficult and easier routes (except when a hard road was required by other reasons, for example for worship). This factor may reflect a stratified knowledge of the area that allowed pastors to trace paths as best functional for the saving of time, manpower, exposure of livestock to the transit, local events - all those situations, in short, of different entities that have happened and still happen in the rural life of the island. To quote F. Cambi,

> *"It is always the story that produces landscapes, operating on natural environmental frameworks through the actions of man. These, in different ways, and with different complexity, overlap the natural substrate and are part of a historical legacy that is progressively enriched with a process comparable to the unstoppable transformation of an individual's genetic heritage, which continue, even after his death, in subsequent generations"* (Cambi 2003: 12).

2.2. The GIS methodology

For the analysis, we used the potentialities offered by GIS -- Geographic Information System applications. The software allowed us, first, to store the resulting data from the field

survey conducted during these years of research and to geo-reference 87 dolmens (about 40% of the total number known for Sardinia). The dolmens were referenced following a review and update aimed for a more precise clarification of the status of findings that led to adding new monuments compared to the status of research of 2009 (Cicilloni 2009). The production of an updated and accurate map of dolmens of the study area and an accurate geo-referencing were made through field surveys but also thanks to the published research on bibliographic and cartographic heritage, and the webGIS database made available by R.A.S - *Regione Autonoma della Sardegna*, through its geo-portal.

With GIS it was possible to perform a series of analyses because the georeference data and shapes of the relief were able to be handled in three-dimensional form using a DEM - Digital Elevation Model (Wheatley & Gillings 2002: 95, 96; Conolly & Lake 2006: 90-111). This is a powerful tool for interpreting physical characteristics of the territorial context. It was also possible to assess, by creating a Cost Surface Model (Wheatley & Gillings, 2002: 137-141; Conolly & Lake, 2006: 214-215, 221-224, 233), the main trends related to travel routes in relation to the geomorphological characteristics of the environment in which it is configured and the settlement pattern examined (Figure 8).

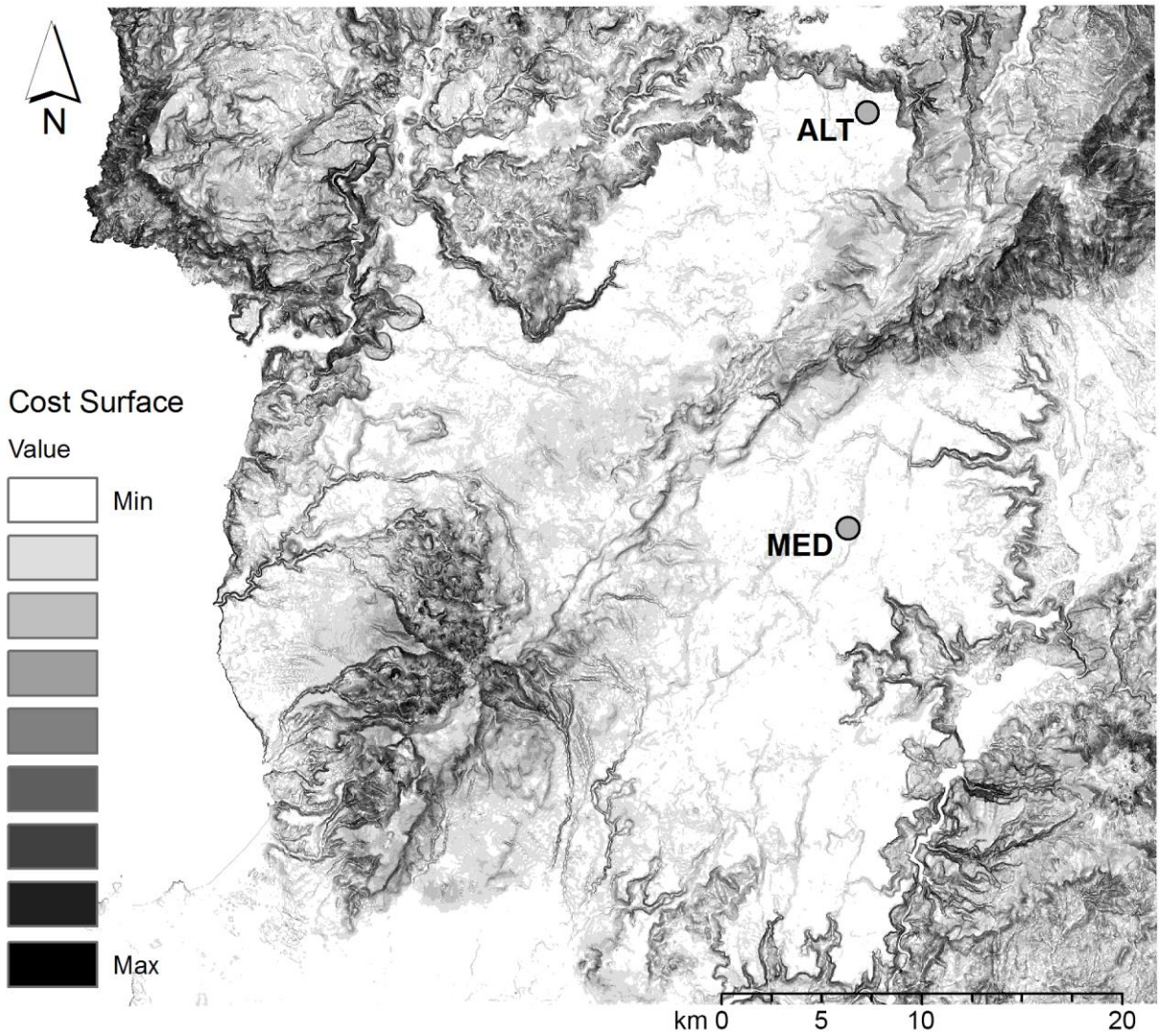

Figure 8.The Cost surface model obtained from a map algebra among the hydrography shapefile and the reclassified slope derived by DTM (Elaboration of M. Cabras).

Seasonal movement tasks related to pastoralism, therefore, were to take place on paths more or less annually repeated near areas in close relationship, for proximity or intervisibility, with many dolmens. We then calculated the Least Cost Path Analysis (LCPA) (Wheatley & Gillings, 2002: 142-143; Conolly & Lake, 2006: 217, 252-255, 262, 294), based on the Cost Surface Model created and calibrated through Reclass and Map Algebra procedures (Wheatley & Gillings 2002: 84, 92; Conolly & Lake, 2006: 187-207), taking into account the degree of slope of the terrain and the presence of wet areas and rivers (for some examples of Cost Surface Model calibration, see Pecere 2006: 185-188; Gherdevich 2009: 56-63; Casarotto *et al.* 2009: 294-300; Camerieri & Mattioli 2013: 334-337).

Identifying the areas with the lowest cost of traveling on the basis of digital cartography was made possible by a process of interpolation between the layers contours and spot elevations of CTR (Technical Regional Map) with 1.10,000 scale. The simulation of the paths often showed close proximity or coincidence with various types of today's roads. The DTM with 10-metre definition can be downloaded from the geo-portal of the *Regione Autonoma della Sardegna*. These applications provide a geographic information tool that contains more information than traditional cartography in proposing a 3-D representation of the shapes of the relief and numerical maps on which to base analyses. So we used a tool that allow us to reproduce conditions hard to quantify in a field survey due to the state of preservation of buildings and a lack of perception on the field of ancient landscape conditions covered by the subsequent human actions.

3. Results

3.1. The analysis towards the median point

By a geo-processing procedure we calculated the median point (Spatial Statistics Tools in ArcGIS) concerning the geographical distribution of dolmens examined. With LCPA we simulated paths that join the dolmens located on the borders of our study area with the geographic median point of the analyzed area. These dolmens are listed in the first column of the Table 1. We operated through this procedure in order to evaluate the spatial relationships of these Least Cost Paths with other non-peripheral dolmens joined on the path towards the median point located on Borore plateau at about 390m above sea level near the Arghentu dolmen. For many of these paths analysis showed that several dolmens, not located in peripheral areas of the global distribution, are located at varying distances to the paths traced by LCPA, often very close.

The Viewshed Analysis (Wheatley & Gillings, 2002: 179-192; Conolly & Lake, 2006: 225-232) calculated with a radius of 2.5 km to a neighborhood of 360° from one observer placed 2m high above ground level in correspondence of each grave has highlighted a complex relationship of the intervisibility of dolmens with several of these Least Cost Paths. This corroborated in our view the relationship of these with important hubs functional to movement within the territory (Figure 9).

3.2. The relationship between dolmens at different altitudes

A second analysis was then performed that simulates links within a sample area, chosen by the authors for elevation between 700 and 800 m above sea level (near the dolmen of Aeddo-Macomer, one of dolmens located at higher altitude), with dolmens located at lower altitudes in order to simulate the activity of transhumance which included shifts towards milder territories during the winter season (Table 2). This analysis also highlighted the results described in Section 3.1.

Table 1. Distances between Least-Cost Paths from peripheral dolmen towards median point.

Dolmen where LCP begins	**Dolmens found along the path and distances** (in metres; accurate to the nearest round figure)
San Sebastiano	Furrighesu 1250, Muttianu 1070
Cannighedda 'e S'Ena	S'Angrone 750, Mura 'e Iscovas 660, Abba Muru 1000, Tuvamene 400, Nucrastala 530, Arghentu 285
Serrese	Nela 500, Muttianu 1070
Aeddo	Edrosu 790, Muttianu 1070
Pedra in Cuccuru	S'Ispreddosu 500, Tuvamene 1300, Arghentu 1000
Mura 'e Putzu	S'Ispreddosu 185
S'Angrone	Sa Perda Piccada 315, Mura 'e Putzu 500, Mura 'e Iscovas 880, Tuvamene 570, Arghentu 530
Mesu Enas	S'Ispreddosu 185
San Basilio	Mura Pranosa 860, Corrizzola 840, Arbu 160, Serbine A 780
Tanca Noa	Edrosu 780
Nurazzolu	Arghentu 270, Nucrastala 530, Meddaris 1100, Tuvamene 415, Mura Fratta 1500, Mura 'e Iscovas 660, Abba Muru 960, S'Angrone 1130.
Abba Muru	Mura 'e Iscovas 1200, Mura Fratta 1550, Tuvamene 410, Nucrastala 540, Arghentu 270
Nurarchei	Arghentu 274, Nucrastala 540, Mura Fratta 1000
Monte Paza	Monte Trigu 350, Iloi 870, Crobecada 62, Nuradorzu 200
Torozzula	Iloi 1400, Crobecada 62, Nuradorzu 196
Filigorri	Nuradorzu 350, Paule Rues 1060, Baratta 450, Lure 0
Monte Lacana	Su Lizzu 470, Su Livrandu 20, Giuanne Pedraghe 410, Muttianu 40, Sa Cobelcada 1000
Mazzarighe A	Lughe 110, Sa Fronte Uda 390, Mazzarighe B 210
Baccarzos	Brancatzu 500, Badde Ide 570, Baratta 530, Paule Rues 310
Noazza	Pradu Lassia 115, Sarbogadas 360, Serbine A 74, Serbine B 170
Carrarzu Iddia	Sa Matta 'e Sa Ide 43, Serbine B 660, Serbine A 770, Perda 'e S'Altare 190, Bidui 50, Noazza 900
Tuide	Muttianu 1060
Nole	Monte Paza 600, Monte Trigu 750, Crobecada 65, Sa Tanca ‘e S’Ozzastru 830, Nuradorzu 200, Meddaris 950, Arghentu 920, Aeddo 820, Edrosu 800

However, in totality, dolmens show an elevation relationship that is not much heterogeneous. It is correct to keep in mind that many monuments are considerably distant from the paths traced by LCPA although sometimes they retain a relationship of intervisibility.

The anomaly, if there is one, may be in the parameters (certainly implementable) that we entered into the software in order to calibrate the Cost Surface Model (Figure 9). Also, we may be in the presence of groups of dolmens that do not have strategic characters but probably other tasks within the territorial organization, perhaps with “symbolic” meanings.

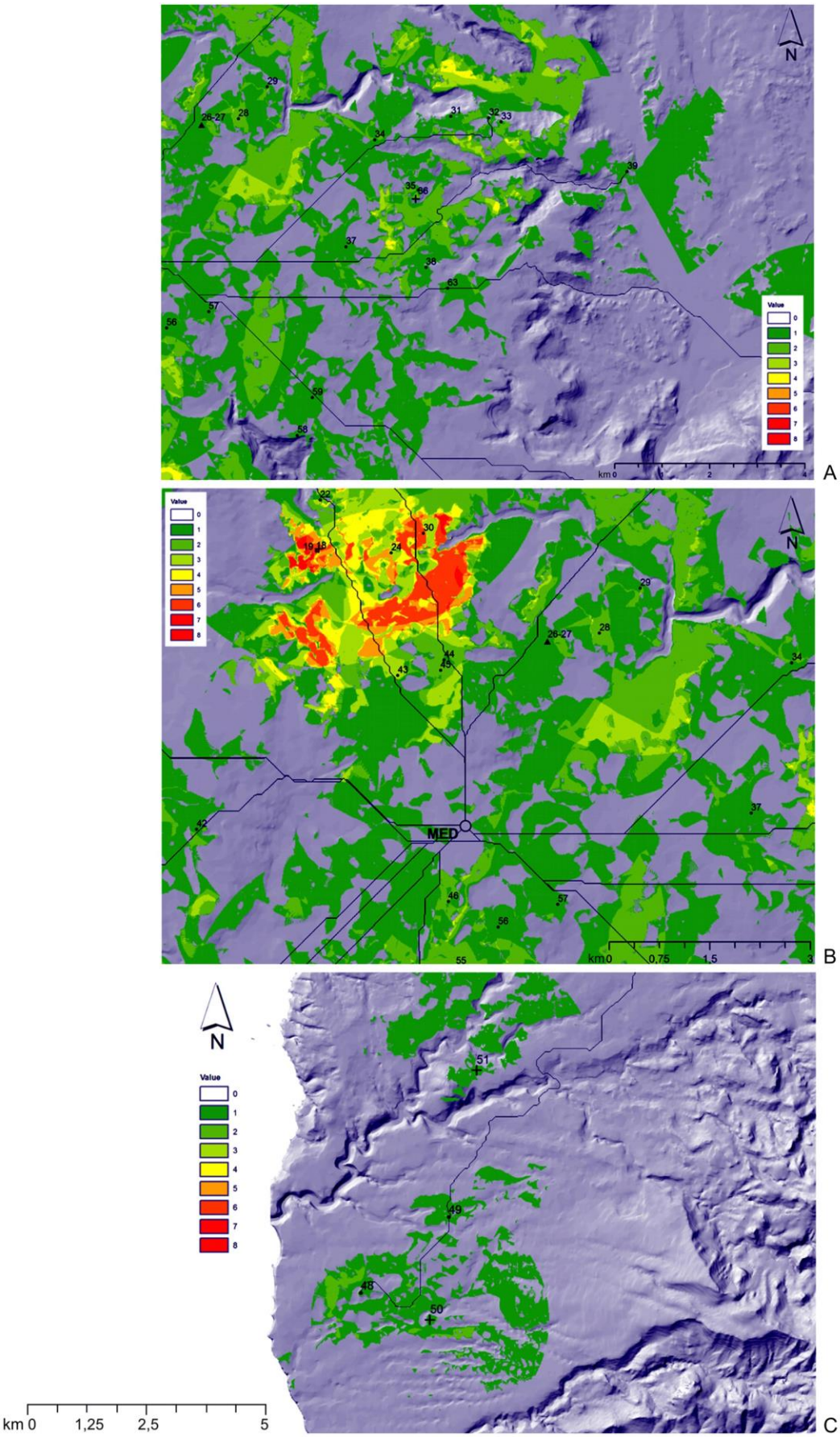

Figure 9. Spatial relationships between Cost paths and dolmens: A, B - The area of Dualchi, Aidomaggiore, Birori, Macomer, Borore, Noragugume; C - The coastal area near Cuglieri (Elaboration of M. Cabras).

Table 2. Least-Cost Path Analysis from the sample area towards dolmen located at lower altitudes. (Distances in metres; accurate to the nearest round figure.)

Arrival dolmen	Dolmens found along the path and distances
Caratzu	Cannighedda 'e S'Ena 1600, Mesu Enas 1080, Pedra in Cuccuru 620, Giuanne Pedraghe 480, Edrosu 800
Cannighedda 'e S'Ena	Mesu Enas 540, Mura 'e Putzu 750, Sa Perda Piccada 1000, S'Angrone 670, S'Ispreddosu 770, Giuanne Pedraghe 440, Edrosu 800
Nurazzolu	Cannighedda 'e S'Ena 1040, S'Angrone 650, Mesu Enas 540, Mura 'e Putzu 750, Sa Perda Piccada 1000, S'Ispreddosu 770, Giuanne Pedraghe 440, Edrosu 800
Mura 'e Iscovas	Sa Perda Piccada 650, Mura 'e Putzu 940, S'Ispreddosu 25, Giuanne Pedraghe 440, Edrosu 800
Torozzula	Iloi 1400, Tanca 'e S'Ozzastru 850, Crobecada 60, Nuradorzu 200, Edrosu 800
San Basilio	Pradu Lassia 160, Sarbogadas 230, Perda 'e S'Altare 1050, Edrosu 800
Mazzarighe B	Mazzarighe A 240, Sa Fronte Uda 390, Lughe 123, Corrizzola 610, Arbu 15, Edrosu 800
Monte Trigu	Iloi 870, Crobecada 60, Nuradorzu 200, Edrosu 800
Succhiau	Mura Fratta 70, Tuvamene 250, Muttianu 230, Edrosu 800
Carrarzu Iddia	Tuide 430
Sa Perda 'e S'Altare	Bidui 700, Edrosu 800
Noazza	Bidui 820, Pradu Lassia 625, Sarbogadas 470, Perda 'e S'Altare 370, Edrosu 800
Baccarzos	Badde Ide 470, Brancatzu 670, Sa Fronte Uda 900, Mazzarighe B 970, Lughe 570, Corrizzola 610, Arbu 10, Edrosu 800
Filigorri	Lure 0, Baratta 450, Paule Rues 1050, Nuradorzu 650, Meddaris 950, Edrosu 800
Monte Lacana	Su Livrandu 20, Serrese 1300, Furrighesu 520, Terra Tenera 2000, Aeddo 900, Nela 1550
Nurarchei	Abba Muru 1340, Succhiau 1850, Mura Fratta 1500,Tuvamene 820, Muttianu 230, Edrosu 800

4. Discussion and conclusions

The study of the location of Sardinian dolmens was carried out taking into account the geomorphology of the environment. The analysis, through precise geo-referencing of each monument and with the application of GIS tools, seems to confirm what has already been highlighted in previous studies with the macroscopic analysis of the phenomenon.

But there are problems: the analysis was carried out taking into account the actual landscape, which, however, in a land almost untouched like Sardinia, with very little human intervention, should not deviate too much from that of the Neolithic and Copper Age. Clearly, landscape changes, not easily appraisable, have occurred, for example in the vegetation coverage of the area and probably in the hydrography of the area. These features of the territory have certainly conditioned the locational choices of human groups. It is also necessary to excavate dolmen burials to find new data, pertinent to the stratigraphic context both palaeobotanical and palaeoenvironmental.

The researches have highlighted some features that recur with a certain constancy. First, many of the dolmens considered are very close to nature trails, sometimes coinciding with canyons or valleys (Figure 9). Moreover, these monuments, as compared with natural ways and, in general, to the surrounding area, are highly visible, although the number of these dolmens is not so great in this area. The data resulting from the analysis however, have not given precise and unequivocal answers, as might be expected, about any connection between dolmens and routes of transhumance. In any case, the study highlighted the strategic nature of the areas interested by the dolmen phenomenon.

Next, it is confirmed that the distribution of the dolmens is scattered over the whole area: in fact, these monuments are rarely grouped in necropoli, but are usually isolated.

To these elements can be added the data constituted by the coexistence, in the same territories such as the plateau of Campeda, of dolmens and the more numerous rock-cut tombs (denominated in local language “Domus de Janas” - fairy houses). The latter are datable to the Late Neolithic and Copper Age, in use at the same time as the dolmens.

All of this leads us to believe that the Sardinian dolmens, as opposed to artificial caves called “domus de janas” (spaces essentially funerary and ritual), should have not just a funerary function, but also some "political" purpose. In fact, these monuments could be interpreted as “signs of territorial demarcation of segmentary societies”, agreeing with the hypothesis proposed by Renfrew (1976), with functions of control and organization of the territory.

During the Late Neolithic (characterized by the Ozieri culture), and the later Copper Age, small groups of farmers and shepherds, who lived locally and were not part of a centralized society of chiefs, in some areas may have felt the need of a first territorial organization: the possession of the territory could be well testified by the presence of megalithic tombs, perhaps pertinent to burials of ancestors, leaders or heroes of the various communities. The scattered distribution of dolmens in this territory and the remoteness of some sites by real and potential paths, highlighted by LCPA, could suggest a kind of "hierarchical structure" of the landscape as regards the funeral area, perhaps following a process of progressive ‘gemmation’ from primary burial phenomena.

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