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RAPPORTO N.285

HEAT CAPACITY MAPPING MISSION (HCMM) PROGRAM

INVESTIGATION HCM-Ø5Ø

STUDY OF GEOLOGICAL STRUCTURE OF SICILY AND OTHER ITALIAN AREAS

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I - INTRODUCTION

The original objectives of the investigation, as specified in the attachement A of the provisions, including:

- the study of geological structure of Sicily ond the analysis of anomalous thermal areas
- the analysis of coastal waters around Sicily and NW Adriatic Sea.

Subsequently, in order to have more chances to receive useful and complete data to fulfil the experimental goals of the investigation, it was decided by mutual agreement between NASA and the P.I. to extend the testarea to other parts of the Italian territory; the primary goal of the experiment being to ascertain the potential of thermal inertia mapping as additional tool to discriminate the geolithological units.

Up to date (see paragraph VI) we are still waiting for a complete pass (visible + night/day I.R.). However, priority passes have been requested according to NASA instructions and three successful orbits over the Italian territory have been announced by NASA (2,8 and 13 April 1979). As soon as the quality of the images will be cheked, we shall ask for the tapes.

Then we shall proceed to a complete evaluation, using the computer programs that have been already prepared (see paragraph II).

Meanwhile, we used incomplete data to test the equipment and part of the software.

In particular, we received one tape (A.A.HHP 783Ø6Ø111-Scene identification AØØ38Ø15ØØ) referring to a night I.R. pass (3 June,1978). The scene is centered on the Tyrrenian sea (coordinates of central points N 41° 46' 11". - E 07° 56' 23"). While the two original test areas (Sicily and NW Adriatic Sea) are out of the scene, the island of Sardinia appears not too cloudy and its image is of particularly good quality (Fig.1). On the other hand, Sardinia could be considered as an excellent alternative target for the experiment. Its structural geology is well known and several geolithological units are distinguishable. The vegetation cover is generally very poor, in particular in June, on some of the outcropping formations (see paragraph III). Therefore, we decided to use Sardinia as a first training test area.

II - TECHNIQUES

II.1 - Employed computers

For the analysis of the first digital HCMM data we used two quite different computers:

a) IBM 370/138 with 700 K byte memory, disks, tape units, line printer for the development of the algorithms.

b) PDP 11•Ø3 with 20 kwords memory, disks, tape unit, TTY, color monitor, three refresh memories for the display of the results in a fast, visible way.
The software of this computer, originally designed for Landsat tapes, has been modified and improved for the HCMM tapes.

Probably in next months we shall link the two computers in order to have a more powerful system.

II.2 - Radiometric calibration

Regarding the measurements of radiant power and the atmospheric corrections, so far we didn't apply any modification to the data. In fact, such a correction doesn't appear necessary while morking on a single pass.
For the three surveys of April (if cloud free) we will take into consideration the ground meteo-data at the moment of the survey as well as the Meteosat data.
We will control if during the 12 hours interval relevant changes occurred, mainly those in water vapour content of the athmosphere.

II.3 - Data handling and software

Our analysis of the available data from HCMM mission of the Explorer-A satellite has suggested to us to produce a suitable software in order to accomplish the mission objectives. We preferred to write our own software instead of trying to adapt the software supplied by NASA. The software production concerned the following items:

A) modification of an existing system software, on mini-computer PDP11-Ø3 provided with a colour monitor, already used to study other kinds of problems, in order to read HCMM tapes (complete)

B) realization of a software package which allows the comparison of images produced by different seasons and/or acquired on different orbits. In order to solve the

registration problems we have written some algorithm to correct rotations, translations, deformations and to minimize the residual differences (complete)

C) development of new programs to calculate temperature values from data indexes, to determine thermal inertia by day-nigth passes comparison, in order to obtain information about the thermal behaviour of the surface (developing)

D) differential analysis by means of mathematical operators to study spatial and temporal evolution of surface thermal parameters (complete)

E) Development of methodologies to merge the data contained on the ECMM tapes with other data (Landsat, topographical and geophysical) (developing).

III - ACCOMPLISHMENTS

III.1 - Description of selected test areas: the island of Sardinia (training test area)

By analysing the frame of Fig.1 for the best understanding of the capability of this kind of information, we have looked for a test area which, should have been fit for that.

In particular, Sardinia Island seems to be offering some peculiar characteristics, not findable, else where, in the surrounding areas.

Geography: the location of the Island, in the central part of the western Mediterranean Sea, warrants a lower cloud coverage than in other sites. Furthermore, the presence of the coast line allows an easier geographic location and the surrounding sea is a natural temperature reference, for the images calibration.

Orography is not exceedingly rough but a clearly differentiated morphology exists. The wooded areas are confined to some well defined sites. Moreover, in the warm season, the vegetation influence is very low, owing to the dryness of the region (Fig.3).

Geology-Lithostratigraphy (Fig.2): a complete cronostratigraphic sequence occurs, from the Cambrian to the present period. Outcropping of single formation is clearly definable, with frequent plateaux within different age limestones (Cambrian, Giurassic and Cretaceous, Eocene and Miocene).

In the North-Eastern part of Sardinia a Hercinian batholith outcrops, as well as somewhere else in the southern area.

Geo-Tectonic framework: structural features of the area are not influenced and troubled by recent plications and folding. In general, tectonic assessment shows a stretching fault style (graben of Campidano and normal faults and wrenches).

Geomorphology: the region shows different areas with peculiar aspects and characteristics:

- alluvial Belt (NW-SE) corresponding to the rift valley of Campidano (South of the island)
- Permo-triassic peneplain with the subsequent mesozoic transgression which presently occurs under the form of isolated tableaux (Central-Eastern part of the Island)
- Plateau basalt with wide lavaflows to be connected to the recent volcanic activity (Pliocene-Quaternary).

Other kind of data: we have the opportunity of correlating the results of the investigation with other available kind of data and information from space platforms and aircrafts.

- -Skylab imagery
- -Landsat passes
- -local thermal infrared aerial surveys
- -pancromatic aerial photography of the whole territory, in different scales and already interpreted
- -aeromagnetic maps (both detailed and regional).

Potential applications: besides the main objectives of the research, one of the most interesting application should be, the possibility of detecting and controlling the high moisture content areas, because of the water supply problems that exist in the region.

III.2 - Preliminary enhancements and results

Only to indicate the aspect of the display from the available CCT, we enclose:

1) A B/W level slicing obtained with a normal stretching of the original histogram (Fig.4). This type of processing is not sufficient, of course, for any kind of soil classification.

However, it is a good guide to discriminate several areas of possible interest. In any case the level slicing will be necessary to quantify the differences between day/night images.

Excluding the areas where the lack of information prevents any useful correlation (rough orography and high elevation sites) some remarks can already made (see Fig.5):

- the largest alluvial deposit is the graben of Campidano, oriented SE-NW in the Southern part of Sardinia. The valley is flat and the forest completely absent. The slicing shows an elongated thermal negative feature in the center of the valley, separating two positive strips. There is a good matching between the state of vegetation and the thermal levels, the darker ones (colder) corresponding to the close-to-bare soil areas. But this feature could also be correlated to the known faults along and across the bottom of the graben. The image also shows that the thermal behaviour of shallow waters of the bays of Cagliari and Oristano (at both ends of Campidano) can be another good target of the investigation.
- In Central Sardinia (NE of Oristano) a linear, very narrow, feature is clearly visible at the boundary between the granites of the NE plateau and the basalts of NW.
- In NE Sardinia some elongated, but broader, features correspond to known morphologic-tectonic alignements, especially to those with SW-NE direction (Hercynian tectonics).
- In at least one case a perfect geometrical correspondence was found between a basalt outcrop (mesa) (10x5 km) surrounded by Miocenic marls. Nevertheless, the level is the same corresponding in other cases, to different realities (for example, to forest). Thermal inertia will be the necessary clue for the discrimination.

2) Fig.6 represents the gradient of thermal image obtained by the following formula :

$$x,Y = \sqrt{\left[\sum_{k=i-1}^{i+1} P_{k,j+1} - \sum_{k=i-1}^{i+1} P_{k,j-1}\right]^2 + \left[\sum_{k=j-1}^{j+1} P_{i+1,k} - \sum_{k=j-1}^{j+1} P_{i-1,k}\right]^2}$$

where x and y are the coordinates of the pixel.

The gradient function being applied to the full information image, it shows very detailed patterns which are useful for a large scale investigation. However, for this first regional approach, this form of presentation seems to be too detailed.

In the near future we shall apply the function not to the original data, but to properly smoothed data, in order to describe the boundaries of the small phenomena, which will appear contoured like the coastal line in Fig.6.

III.3 - New data provided by HCMM

At this time, owing to the lack of day/night passes, it is impossible to prove the usefulness of the new tool, i.e. thermal inertia. However, it can be considered as a new datum the thermal imaging of large areas with a geometrical resolution higher than that obtained by meteorological satellites. The merging of this type of data with Landsat multispectral imagery and with stereophotography from the space seems already feasible and useful.

IV - DATA QUALITY AND DELIVERY

A) Digital data

Up to date we received two digital tapes: the first concerning an U.S.A. area (California) (only Day Visible/Day I.R.); the second on Italy (only Night I.R.).

Therefore it was impossible any evaluation of thermal inertia. The quality is good and the format is proper.

B) Analog data

We received many images always incomplete for the tasks of the investigation (see attached list), even on European and non European areas extra Italy (often cloudy). The photographic quality of playback is good, but only in few cases we received both positive and negative transparencies.

We would like to receive more information regarding the relationship between the gray-scale the gray-content of the image, and the histogram of the relative tape.

Regarding the delivery, because of the custom expenses, we shall prefer a lower number of shippings containing more images.

V - FUTURE WORK

As soon as the three announced complete passes of 2,8 and 13 April, 1979 will become available, we shall select, on the base of the quality of data, the final test area(s) for the experiment.

- Products:

The software will be improved by the end of September. Besides the standard product (ATI) we intend to develop some other thematic maps, namely:

- the gradient function applied to the smoothing of the original data (day visible/I.R.-night I.R.)
- the comparison between the boundaries of the contours of the three frames above
- the comparison between the gradient functions in different passes in order to detect the shape changes with the time
- the overlay of the gradient function on the level slicing of ATI
- the gradient function applied to ATI function.

For investigations in small areas we shall try to apply the Laplacian operator:

$$L(x,y) = \frac{\partial^2 z}{\partial x^2} + \frac{\partial^2 z}{\partial x^2}$$

to the configurations described above.

- The investigation will be then developed by the merging of thermal data with Landsat, meteorological geological and geophysical data.

FIGURE CAPTIONS

Fig. 1 - Original frame

Fig. 2 - Geolithological map of Sardinia island (scale 1:1.000.000)

LEGENDA

1 - Recent and present alluvial deposits (Pliocene-Quaternary)

2 - Marls and calcarenites (Miocene-Eocene)

3 - Limestones (Giurassic-Cretaceous)

4 - Evaporites (Triassic)

5 - Slaty arenaceous complex (Silurian-Ordovician)

6 - Skarn and hornfels

7 - Slaty clays with carbonatic lenses (Cambrian)

8 - Volcanites

9 - Hercynian batholyth

10 - Faults.

Fig. 3 - Sketch of the vegetation distribution in Sardinia (Summertime) from Landsat images.

- black areas : forest
- white areas : grass or cultivated
- dotted areas : dry, bare soils
- framed areas : test-site under investigation

Fig. 4 - B/W slicing. Contrast stretching of the original I.R.HCMM images. 8 levels (warm=white, cold=black).

Fig.5-The main featuresextracted from the comparison of Fig.4, Fig.2 and Fig.3.

Fig.6 - Gradient of the original scene (3 levels)

DATA	N°CODICE	IMMAGINI HCMM DAY VIS	DAY IR	NIGHT IR	AREA IMMAGINI
28-5-78	A0032-12340-1	.	—	—	ITALIA OR. CENTRO SETTENTRIONALE
30-5-78	A0034-2120-3	—	—	.	EUROPA OCC.(ING.FRANCIA,BELGIO,P.BAS
2-6-78	A0037-01310-3	—	—	.	EUROPA ORIENTALE
2-6-78	A0037-01320-3	—	—	.	ITALIA CENTRO MERIDIONALE
3-6-78	A0038-12460-1	.	—	—	ITALIA (escluse CALABRIA e isole)
3-6-78	A0038 -12460-2	—	.	—	ITALIA (escluse CALABRIA e isole)
3-6-78	A0038-12440-1	.	—	—	SICILIA e AFRICA SETT.
3-6-78	A0038-01490-3	—	—	.	EUROPA OCCIDENTALE
3-6-78	A0038-01500-3	—	—	.	ITALIA CENTR. SARDEGNA CORSICA
8-6-78	A0043-12380-1	.	—	—	ITALIA CENTRO MERID. e SICILIA
8-6-78	A0043-12380-2	—	.	—	ITALIA CENTRO MERID. e SICILIA
8-6-78	A0043-12370-1	.	—	—	SICILIA MERID. TUNISIA
12-6-78	A0047-12140-1	.	—	—	NON INTERPRETATA
12-6-78	A0047-12140-2	—	.	—	NON INTERPRETATA
18-6-78	A0053-12260-1	.	—	—	ITALIA CENTRO SETT.ed EUROPA OR.
18-6-78	A0053-12260-2	—	.	—	ITALIA CENTRO SETT.ed EUROPA OR.
18-6-78	A0053-12220-1	.	—	—	AFRICA (LIBIA)
18-6-78	A0053-12220-2	—	.	—	AFRICA (LIBIA)
20-6-78	A0055-02070-3	—	—	.	BALEARI e COSTA SPAGNOLA

DATA	N° CODICE	IMMAGINI HCMM DAY VIS	DAY IR	NIGHT IR	AREA IMMAGINI
20-6-78	A0055-02050-3	—	—	.	EUROPA OCCIDENTALE
24-6-78	A0059-12370-1	.	—	—	ITALIA (escl.CALABRIA,SICILIA)
24-6-78	A0058-12370-2	—	.	—	ITALIA (escl.CALABRIA,SICILIA)
24-6-78	A0059-12350-1	.	—	—	CALABRIA,SICILIA,TUNISIA
24-6-78	A0059-12350-2	—	.	—	CALABRIA,SICILIA,TUNISIA
30-6-78	A0065-01530-3	—	—	.	SARDEGNA, CORSICA
30-6-78	A0065-01550-3	—	—	.	NON IDENTIFICATA
30-6-78	A0065-01510-3	—	—	.	EUROPA OCCIDENTALE
5-7-78	A0070-12410-1	.	—	—	ITALIA (escl. CALABRIA e isole)
5-7-78	A0070-12410-2	—	.	—	ITALIA (escl. CALABRIA e isole)
5-7-78	A0070-12400-1	.	—	—	SICILIA,AFRICA (NAPOLI,SARDEGNA)
5-7-78	A0070-12400-2	—	.	—	SICILIA,AFRICA (NAPOLI,SARDEGNA)
11-7-78	A0076-01550-3	—	—	.	OLANDA
11-7-78	A0076-01570-3	—	—	.	COSTA FRANCESE e SPAGNOLA OR.
22-7-78	A0087-02000-3	—	—	.	EUROPA OCCIDENTALE
22-7-78	A0087-02020-3	—	—	.	COSTA FRANCESE e SPAGNOLA OR.
21-8-78	A0117-01190-3	—	—	.	ITALIA MERID.con ISOLE e TUNISIA
24-8-78	A0120-13080-1	.	—	—	COSTA FRANCESE OCCIDENTALE
24-8-78	A0120-13080-2	—	.	—	COSTA FRANCESE OCCIDENTALE

		IMMAGINI HCMM			
DATA	N° CODICE	DAY VIS	DAY IR	NIGHT IR	AREA IMMAGINI
24-8-78	A0120-13060-1				COSTA FRANCESE e SPAGNOLA OR.
24-8-78	A0120-13060-2				COSTA FRANCESE e SPAGNOLA OR.
1-9-78	A0128-12190-1				ITALIA CENTRO SETT. e JUGOSLAVIA
1-9-78	A0128-12190-2				ITALIA CENTRO SETT. e JUGOSLAVIA
1-9-78	A0128-12170-1				ITALIA MERIDIONALE
1-9-78	A0128-12170-2				ITALIA MERIDIONALE
6-9-78	A0133-12130-1				ITALIA CENTRO SETT.
6-9-78	A0133-12130-2				ITALIA CENTRO SETT.
6-9-78	A0133-12110-1				ITALIA MERIDIONALE
6-9-78	A0133-12110-2				ITALIA MERIDIONALE
7-9-78	A0134-12300-1				NON IDENTIFICATA
7-9-78	A0134-12300-2				NON IDENTIFICATA
7-9-78	A0134-12290-1				SICILIA e TUNISIA
7-9-78	A0134-12290-2				SICILIA e TUNISIA
5-10-78	A0162-12530-1				EUROPA CENTRO OCCIDENTALE
5-10-78	A0162-12530-2				EUROPA CENTRO OCCIDENTALE
5-10-78	A0162-12520-1				SARDEGNA e COSTA FRANCESE, SPAGNOLA
5-10-78	A0162-12520-2				SARDEGNA e COSTA FRANCESE, SPAGNOLA
5-10-78	A0162-12500-1				COSTA OR. dell'AFRICA SETT.

IMMAGINI HCMM

DATA	N° CODICE	DAY VIS	DAY IR	NIGHT IR	AREA IMMAGINE
5-10-78	A0162-12500-2	—	.	—	COSTA OR. dell'AFRICA SETT.
18-10-78	A0175-01000-3	—	—	.	MARE
27-10-78	A0184-12590-3	—	—	.	SPAGNA COSTA ORIENTALE
29-10-78	A0186-11580-1	.	—	—	ITALIA CENTRO MERID. JUGOSLAVIA
29-10-78	A0186-11580-2	—	.	—	ITALIA CENTRO MERID. JUGOSLAVIA
16-11-78	A0204-01340-3	—	—	.	FRANCIA
16-11-78	A0204-01360-3	—	—	.	COSTA ITALO-FRANCO-SPAGNOLA
16-11-78	A0204-01380-3	—	—	.	AFRICA SETTENTRIONALE
5-12-78	A0223-11500-1	.	—	—	JUGOSLAVIA
5-12-78	A0223-11500-2	—	.	—	JUGOSLAVIA
6-12-78	A0224-12090-1	.	—	—	NON IDENTIFICATA
6-12-78	A0224-12090-2	—	.	—	NON IDENTIFICATA
6-12-78	A0224-12070-1	.	—	—	ITALIA,JUGOSLAVIA CENTRO SETT.
6-12-78	A0224-12070-2	—	.	—	ITALIA,JUGOSLAVIA CENTRO SETT.
6-12-78	A0224-12050-1	.	—	—	ITALIA MERID. e SICILIA
6-12-78	A0224-12050-2	—	.	—	ITALIA MERID. e SICILIA
7-12-78	A0225-12260-1	.	—	—	ITALIA SETTENTRIONALE
7-12-78	A0225-12260-2	—	.	—	ITALIA SETTENTRIONALE
7-12-78	A0225-12250-1	.	—	—	ITALIA CENTRO SETT.

IMMAGINI HCMM

DATA	N° CODICE	DAY VIS	DAY IR	NIGHT IR	AREA IMMAGINE
7-12-78	A0225-12250-2	—	—	—	ITALIA CENTRO SETT.
7-12-78	A0225-12230-1	—	—	—	TUNISIA e SICILIA OCC.
7-12-78	A0225-12230-2	—	—	—	TUNISIA e SICILIA OCC.
8-12-78	A0226-12410-1	—	—	—	AFRICA SETTENTRIONALE
8-12-78	A0226-12410-2	—	—	—	AFRICA SETTENTRIONALE
29-12-78	A0247-12360-3	—	—	—	NON IDENTIFICATA
3-6-78	A0038-01480-3	—	—	—	GERMANIA e AUSTRIA
3-6-78	A0038-01490-3	—	—	—	SARDEGNA,CORSICA e COSTA ITAL.FRANC.
3-6-78	A0038-01510-3	—	—	—	AFRICA SETTENTRIONALE

Fig. 1

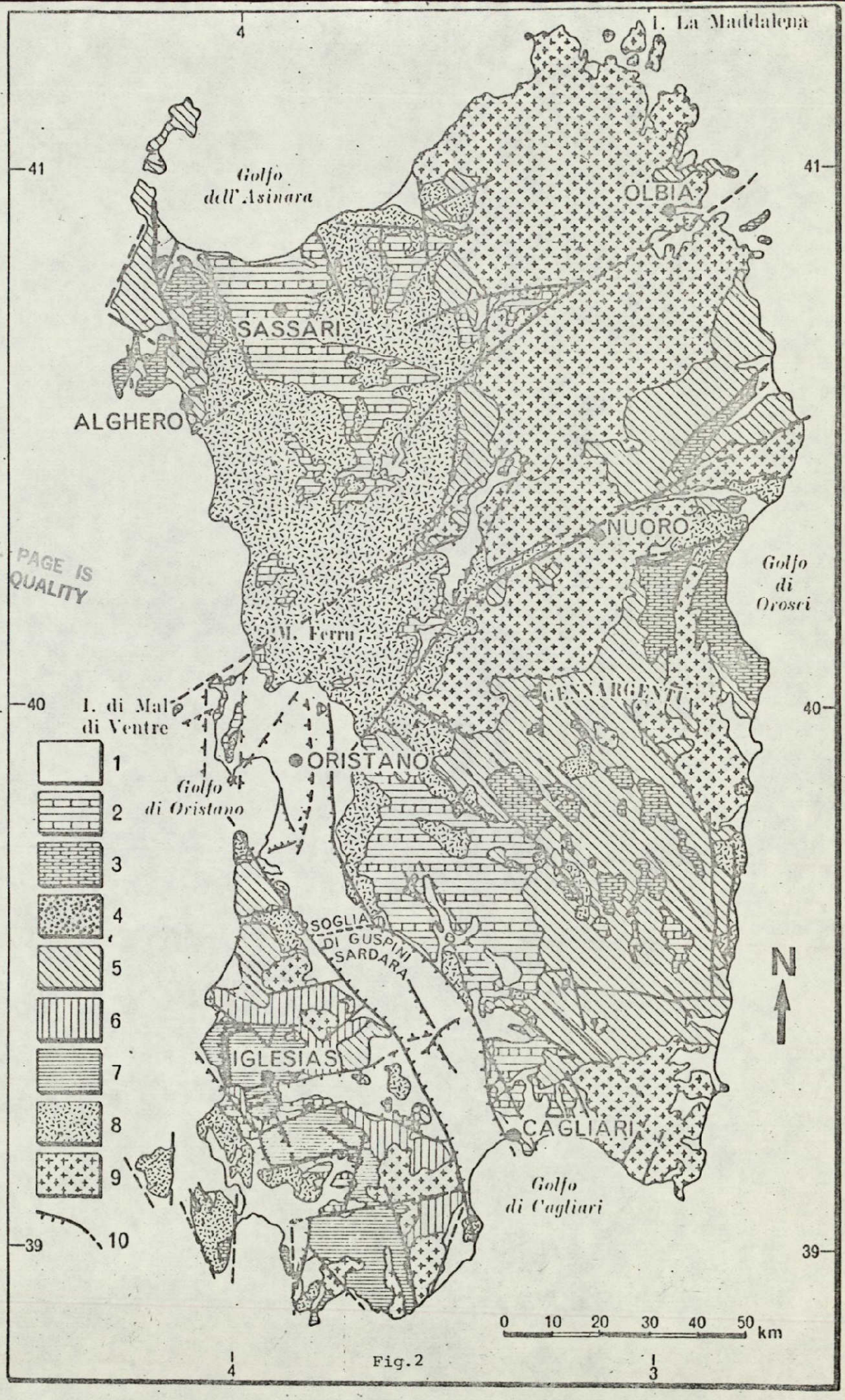

Fig.2

Fig.3

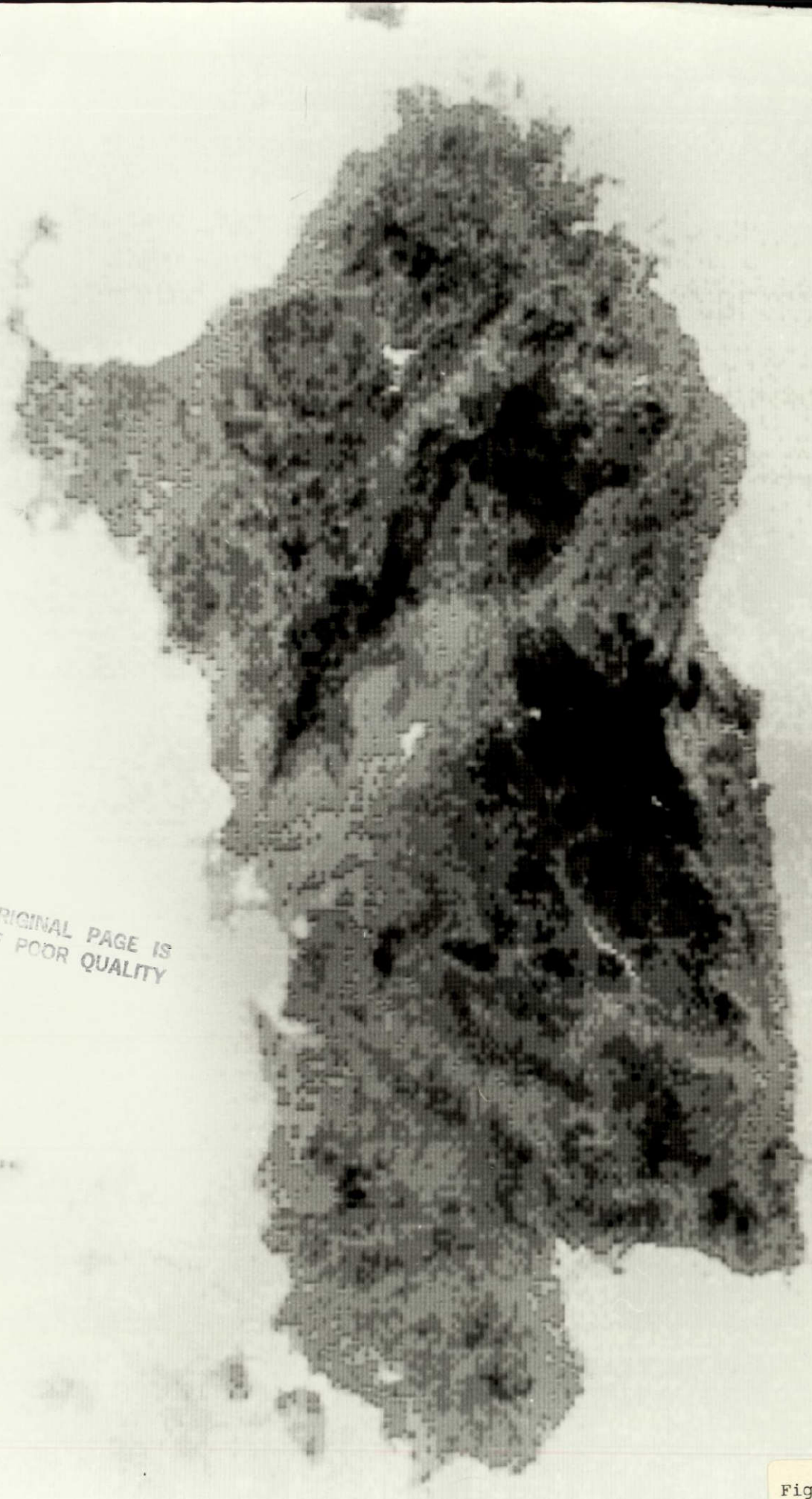

Fig.4

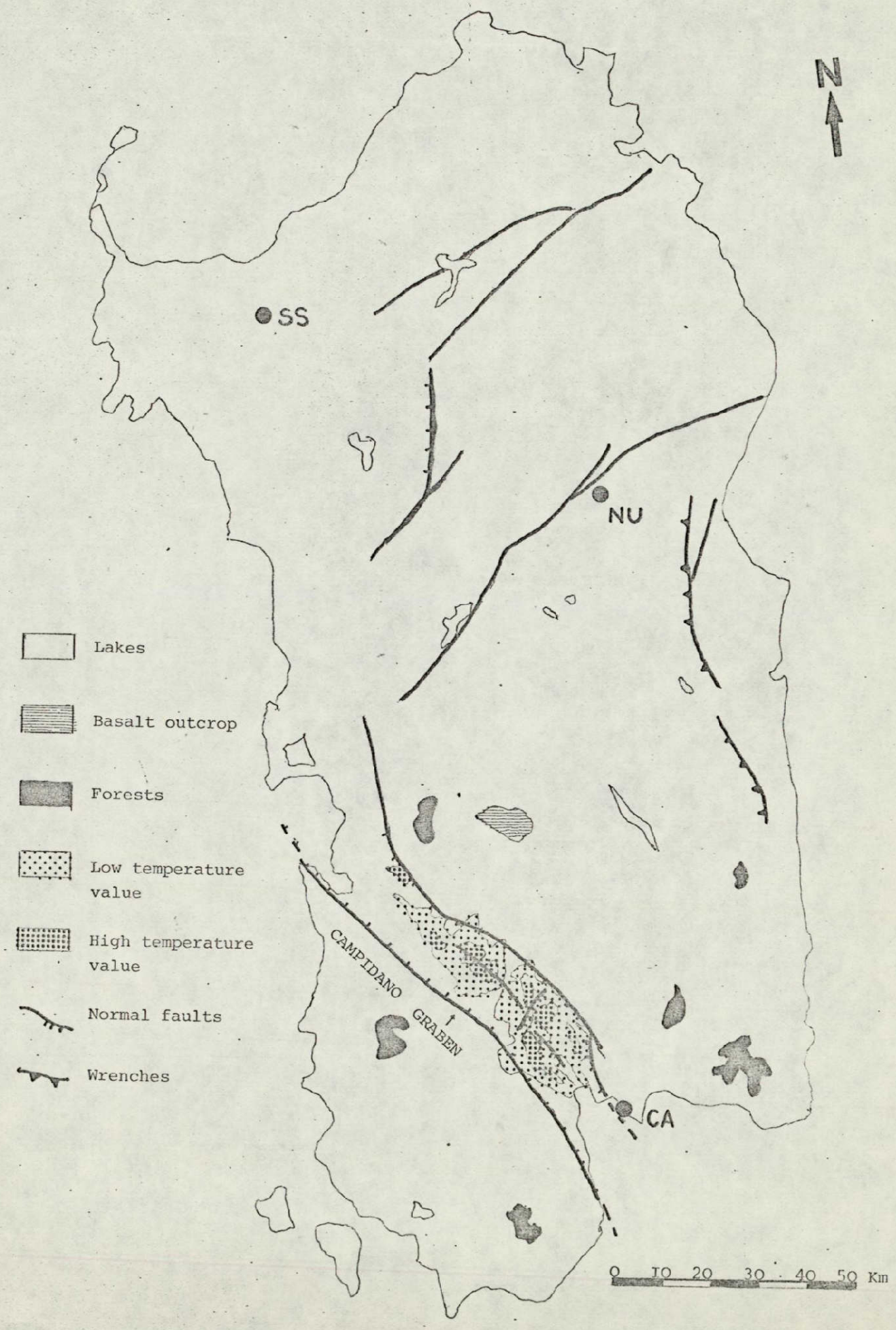
N
SS
NU
CA
CAMPIDANO
GRABEN
Lakes
Basalt outcrop
Forests
Low temperature value
High temperature value
Normal faults
Wrenches
0 10 20 30 40 50 Km

Fig.5

Fig.6


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