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Environmental study on a badland area in Southern Italy *

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ABSTRACT: The Sant' Arcangelo basin is part of the catchment area of the Agri river and belongs to the Basilicata region in Southern Italy. It consists of conglomerates, sands, and clays of Plio-Pleistocene age. In this zone one of the most widespread badland area of Europe has developed due to unfavourable natural conditions, such as recent tectonic activity, and the semi-arid climate with frequent events of heavy precipitation. Furthermore, the degradation of vegetation and soil has been triggered by strong human impact (excessive land utilisation). The region is a good example of the high effectiveness of actual morphodynamics directed by the climate. It also represents the natural problems of this economically underdeveloped part of Italy ("Mezzogiorno"). In the framework of this study two thematic maps were produced and printed, i.e. a Geomorphological Base Map and a Geomorphological Study Map at scales of 1:50,000 and 1:10,000, respectively. The 1:50,000-scale map is an image map based on a high-resolution space image acquired by a Russian KVR-1000 photographic system in 1990. This image is unique because due to the very low sun elevation at the time of acquisition the characteristic badland morphology, consisting of earth cones, is distinctly brought into relief by the illumination of the sun. The second map shows a subset of the first one superimposed with cartographic elements, e.g. signatures for earth cones and piping gullies, derived from large-scale aerial photographs dating from 1976. This paper describes the environmental setting and also the changes thereof observed in the study area derived from interpretation of both satellite image maps, extensive field studies and analysis of other collateral information.

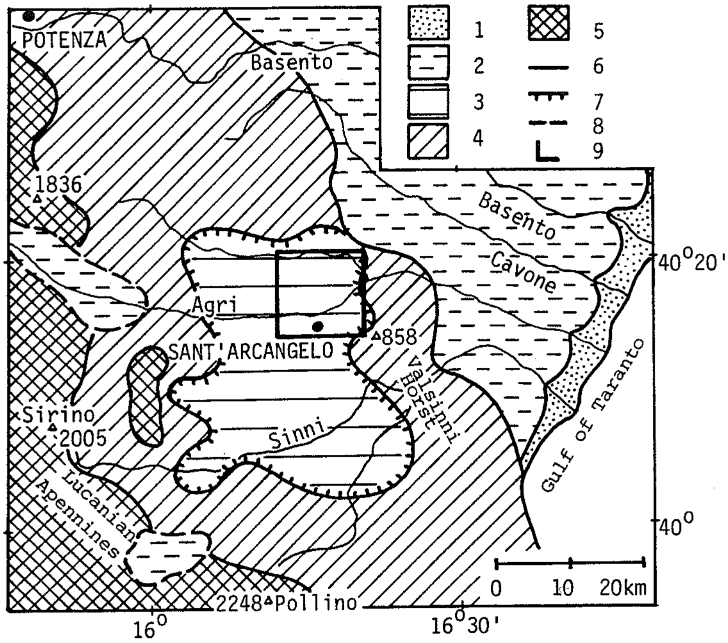
1 INTRODUCTION

Large-scale topographic mapping as well as image interpretation using satellite imagery has become an important issue during the last few years since spaceborne high-resolution image data have been cleared for sale. Moreover, the potential of modern satellite data imply that, e.g., geoscientific projects, which rely on up-to-date information of the earth surface, can be done more cost-effective than with aerial surveys. A review of the current status and future possibilities of topographic mapping from space is summarized in Konecny (1995). In our study for the first time high-resolution KVR-1000 satellite image data are used to map and delineate meso-scale geomorphological features on earth which are normally not detectable with other spaceborne remote sensing systems. These data should support a comprehensive environmental analysis of a badland area.

2 GEOGRAPHICAL POSITION AND CHARACTERISTICS OF THE STUDY AREA

The location of the study area is shown in the inset map on the Geomorphological Base Map 1: 50,000 enclosed in this volume. It is part of the Agri river basin which covers an area of some 1700 km^2 extending from the crest of the Southern Apennines to the Gulf of Taranto. According to the administrative division of Italy the study area belongs to the Basilicata region and to the provinces of Matera and Potenza, respectively. The area covered by the map 1:50,000 is situated in an intramontane depression which is called Sant' Arcangelo basin (for its position within the main geological and landscape units see Figure 1). The development of this basin resulted from the following circumstances (Verstappen 1983, 292): Between the borders of the Apennine ranges which

* Please see Geomorphological Maps in the inside of backcover



Explanations: 1 = coastal plain; 2 = softly undulated to hilly relief of the Apennine Foreland, including marine terraces, composed of marine, in intramontane basins lacustrine, sediments (Plio-Pleistocene); 3 = hilly, dissected relief composed of clays and sands (Plio-Pleistocene); 4 = hilly to mountainous relief predominantly composed of flysch (Miocene-Cretaceous); 5 = mountain, partly high mountain, relief predominantly composed of limestones (Cretaceous-Triassic); 6 = boundaries of the landscape units; 7 = margin of Sant' Arcangelo basin; 8 = other intramontane basin; 9 = area of the Geomorphological Base Map 1:50,000.

Figure1. Position of the Sant' Arcangelo basin within the surrounding landscape units.

have the tectonical position of a relatively uplifted overthrust in the W and the Valsinni horst in the E a structural depression has been formed by orogenic processes mainly in the Pliocene and early Pleistocene ages. As a consequence of a transgression of the sea at that time the depression was filled by weak marine sediments, which were evacuated very rapidly in the Upper Pleistocene contributing much to the widening of the basin. The surroundings of the basin are predominantly composed of flysch, in the mountainous regions of the Apennines in the W also of limestones. Further information on geology and geomorphology can be obtained from Sestini et al. (1992), Verstappen (1983) and from the titles cited below.

The climatic conditions of Southern Italy can be described as subtropical characterized by a comparatively high temperature level and a mediterranean-type of annual distribution of precipitation with a marked minimum in summer and a maximum in autumn. Table 1 presents some basic climatic data for two stations in the vicinity of the study area. According to the climatic regionalisation of Italy as elaborated by Tichy (1985), Potenza belongs to the mountain climate of the Southern Apennines and Taranto to the subtropical coast climate, whereas the hilly regions in the basin of Sant' Arcangelo represent intermediate climatic conditions. For all these regions high variabilities of the amounts of precipitation combined with high intensities are very typical. This fact which, e.g., has been worked out by Cantú (1977) is very important for the badland formation as discussed below.

According to the geoecological conditions the entire study area can be classified as potential woodland (mediterranean oak forest dominated by *Quercus ilex*, at higher altitudes also submediterranean plant communities), but today woods only cover marginal areas. The reduction of

Table1. Climatic data (1901-30) for Potenza and Taranto (from Cantú 1977).

Station	Potenza (40°38' N, 15°48' E; elevation 826 m)	Taranto (40°28' N, 17°13'E; elevation 16 m)
Temperature, mean of coldest month	3.2°C (Jan.)	8.8°C (Jan.)
Temperature, mean of warmest month	20.8°C (Aug.)	25.7°C (Aug.)
Temperature, annual mean	11.6°C	16.8°C
Precipitation of driest month, mean/number of days	29.2 mm/3.4 days (July)	16.1 mm/1.7 days (Aug.)
Precipitation of wettest month, mean/number of days	115.0 mm/10.4 days (Nov.)	71.6 mm/6.5 days (Oct.)
Precipitation, annual mean/number of days	890.7 mm/92.2 days	476.0 mm/57.5 days

Annotation: The number of days refers to precipitation of 1 mm per day or more.

the natural vegetation was due to the socioeconomic development of the last centuries as has been worked out by Tichy (1962) with special regard to the precarious relationship between landowners and rural population, weak laws and the expansion of pastures and farmland ignoring ecological requirements. Corresponding to unfavourable natural conditions as well as to the historical and social aspects of the land utilisation systems, the population density in Basilicata is the lowest of all regions in the Italian peninsula (1981: 60 inhabitants per km^2).

3 ASPECTS OF BADLAND FORMATION

The term "badlands" is used for landscapes which are densely carved by a compact system of gullies formed by erosion processes. Among these processes sheet erosion, rill erosion and gully erosion are of special importance. Commonly, these types of morphodynamics are summarized by the term „soil erosion“ which is misleading because it does not mean that only soil is removed but also includes the erosion of bedrock. The formation of badlands is determined by several environmental factors of the involved area, such as geology, relief, precipitation structure , vegetation cover, and land utilisation. The erodibility of a certain surface largely depends on the character of the soil, e.g. its permeability and its capacity of water storage which both are controlled by the prevailing grain size. The actual erosion rate is a result of the quantity and intensity of precipitation, because the falling raindrops separate the single grains of the soil by splash and induce their downslope transport by a flow process called rainwash. High precipitation within short spaces of time (50-100 mm/h) is most effective in initiating and accelerating soil erosion. It is a worldwide hazard, especially in agricultural regions of the semiaride and aride zones, which has already attracted much attention by scientists of different disciplines.

In the Italian peninsula badlands are very frequent in the areas of the Subapennine which consist of Pliocene and Pleistocene clays. Two main types with different forming processes and individual appearance are distinguished.

- Calanchi (sing. calanco) are landforms consisting of densely dissected, steep, bare slopes and channels with sharp, narrow crests between them.
- Biancane (sing. biancana) is the term used for cones and hummocks rising a few meters above pediment-like surfaces of low inclination.

Both types of badlands develop very fast, once the subsurface material is exposed to atmospheric effects, e.g. by a landslide. Thus very high erosion rates can be observed (values of surface lowering in the order of 2-3 cm/year are reported by Alexander 1982), but there is a high temporal and spatial variability to be considered. Although both features result from different pedological and lithological properties of the substrate (for details see Alexander (1982) and Vittorini (1977) - the latter including excellent photographs, especially showing the surface structures of biancane) they often occur within the same badland area together with other processes of mass movement as is the case in Sant' Arcangelo basin (Figure 2). Due to the ability

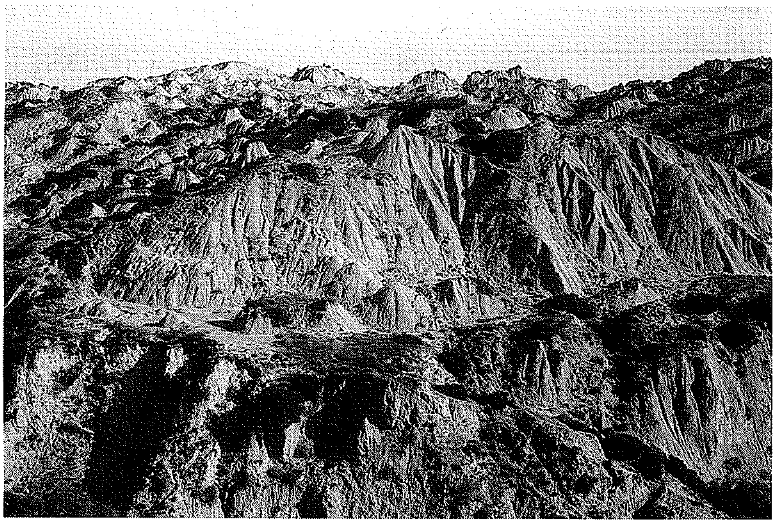


Figure 2. Badland area with calanchi and biancane near Alianello in the Sant' Arcangelo basin.

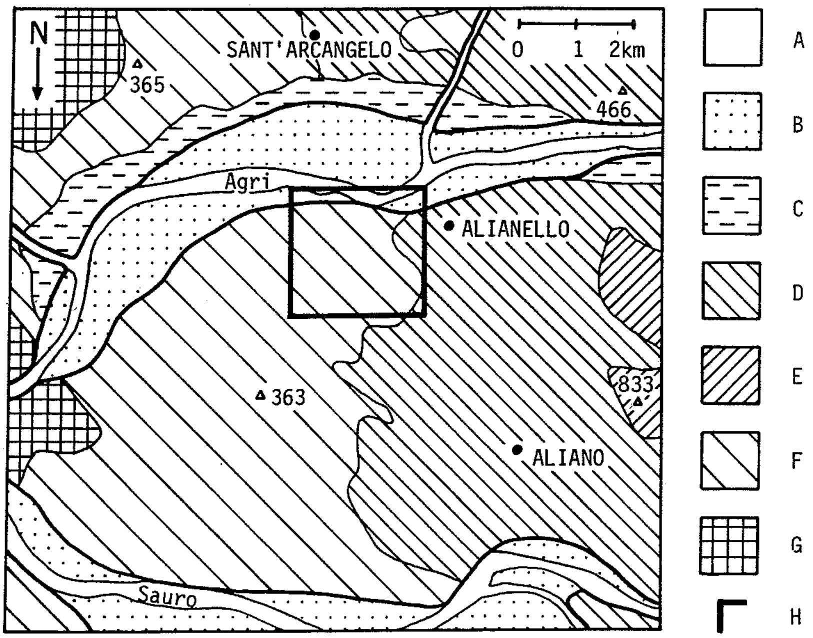
of the sediments to form a dispersion in water both features are combined with a subterranean drainage network consisting of pipes (up to several meters in diameter) which result from the percolation of rainwater into cracks. Some authors (e.g. Guerricchio & Melidoro 1982) emphasize the role of deeper disturbances of the subsurface layers in badland formation, as they can occur due to the neotectonic activity affecting all of Southern Italy (e.g. the catastrophic earthquake in November 1980).

4 BADLANDS IN THE STUDY AREA

The Geomorphological Base Map 1:50,000 covers the major part of one of the largest badland areas in Italy, which is situated in the NE part of Sant' Arcangelo basin. Figure 3 is a combined classification of geology (taken from Ogniben 1969), geomorphology (partly with regard to Verstappen 1983) and land use for the area of the map. As can be seen, marly clays of marine origin (Pliocene to Pleistocene age) are most widespread such that vast areas are affected by soil erosion processes. The features described above are best developed near the centre of the map which has therefore been enlarged and thematically revised in the Geomorphological Study Map 1:10,000, which is also enclosed in this volume. Biancane and associated piping gullies are of special significance for the morphodynamics and configuration of the mesoscale landforms. Furthermore, a concentration of these badland features on southward facing slopes can clearly be seen. This fact is a result of the gentle northern dip of the clay beds as well as of the desiccation of the soil in the dry summer season which is most effective in these expositions (Verstappen 1983, 299). In general the perfect development of badlands in the study area can be interpreted as a result of the concurrence of all the triggering mechanisms mentioned above, i.e. bedrock composed of weak material, rough relief with comparatively large relative heights favourable to rapid removal of the eroded substrate, heavy precipitation after a very dry summer, mistakes in land utilisation over generations and, finally, natural disasters like earthquakes.

Both maps clearly show that intensive agricultural activities are more or less restricted to the valley bottoms of Sauro and especially of the Agri river. Here the construction of artificial embankments combined with land reform has created areas which are no longer affected by inundation and, by means of irrigation (some superficial installations can be seen in the maps), provide good conditions for the cultivation of fruit ("Giardini di Sant' Arcangelo"). In the rest of the study area extensive land utilisation prevails (livestock rearing on former arable land) except for rather small patches of ploughed land and fruit or olive trees in the vicinity of the settlements. Due to the loss of land suitable for agriculture and other socioeconomic effects many farms have been abandoned.

In the Geomorphological Study Map variations of



Explanations:

area	geology	landforms	utilisation
A	recent alluvial sediments (Holocene)	present river beds (fiumare type), mostly within artificial embankments	no utilisation
B	subrecent alluvial sediments (Holocene)	valley bottoms outside of artificial embankments	mostly intensive agriculture based on irrigation
C	older alluvial sediments (Holocene)	terraced areas at the margin of the valley botttoms	partly intensive agriculture based on irrigation
D	fine sand of Aliano (Pleistocene)	hilly, dissected relief with soil erosion features	mostly extensive agriculture, olive trees, partly arable land, remnants of forests
E	conglomerates of Castronuovo (Pleistocene)	hilly, less dissected relief with few soil erosion features	arable land, remnants of forests
F	Marly clays, partly sands of marine origin (Upper Pliocene - Lower Pleistocene)	hilly, dissected relief comprising the areas most heavily affected by soil erosion	no utilisation possible, partly extensive agriculture or arable land after amelioration
G	clays, conglomerates, marls and flysch of the Sicilide complex (Eocene to Miocene), partly comprising overlying sands (Lower Pliocene)	hilly, less dissected relief with few soil erosion features	mostly arable land, partly extensive agriculture

H = area covered by the Geomorphological Study Map 1:10,000

Figure 3. Classification of geology, landforms and utilisation of the area of the Geomorphological Base Map (geology after Ogniben 1969, simplified).

the distribution of biancane and piping gullies in the period 1976-1990 can be observed. Obviously, the overall number of badland forms has increased in general, but there are also areas (e.g. near Masseria Soldano or W of Cugno di Manco) where the hummocks have disappeared. The reason for that is bulldozing, which is frequently used in Italian badland regions to produce slope profiles suitable for agriculture, especially for growing wheat (Figure 4). Other attempts of amelioration include contour ploughing or the construction of dams to raise local erosional bases. The best approach in

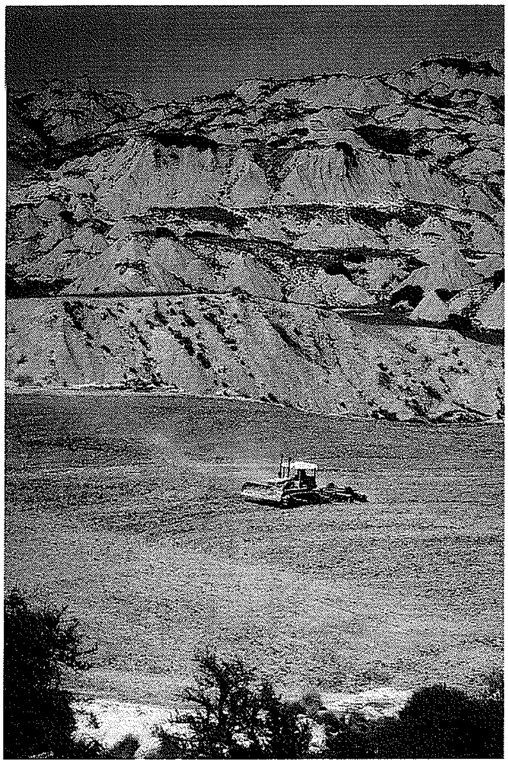


Figure 4. Bulldozing in the badlands near Alianello.

most cases would probably be the afforestation of slopes, though this is obviously not practised in the study area. Until now, the degradation of vegetation and soil could not yet be reduced to a substantial extent so that in the near future not only farm land but also settlements will continue to be endangered by erosion processes. In the past the inhabitants of Alianello had to leave their village because of the severe damage to the houses due to erosional processes and earthquakes.

5 HIGH-RESOLUTION KVR-1000 SATELLITE IMAGE

As mentioned previously, two geomorphological maps at scales of 1:50,000 and 1:10,000, respectively, have served as a topographic basis for the interpretation process. Both maps can be considered as image-based maps. In contrast to most other image maps, e.g. orthophoto maps derived from aerial photographs, the image source is a Russian high-resolution panchromatic KVR-1000 satellite image. Further information on KVR-1000 photographs can be found in the publications of Marek & Weigelt (1993), Kostka & Sharov (1993), Kaufmann, K.-U. & Buchroithner (1994), and Kaczynski et al. (1995). These authors have shown the applicability of KVR-1000 image data, either in analogue or in digital format, in terms of up-dating old maps of urban areas at scales of 1:25,000 up to 1:10,000, whereas in this study a natural landscape is considered.

Detailed information on the geometric processing of the digital KVR-1000 image data used in this work has already been published in Kaufmann, V. & Fastner (1995). For the sake of clearity, however, a short summary of the image rectification process is given: The KVR-1000 panoramic photograph was acquired on December 30, 1990 during a Russian KOSMOS satellite mission. The focal length of the panoramic camera is given nominally with 1000 mm, the original image size is 18cm by 18cm, and the mean scale of the photographs is 1:220,000, as reported in the literature. The analogue black-and-white photograph was scanned and provided in digital format (DD-5) by the Russian State Center "Priroda". Since the imaging geometry of the KVR-1000 camera system is still a military secret and therefore not known to the public, the rectification of the image data into the Italian Gauss-Boaga co-ordinate system was carried out using a 4-parameter Helmert transformation (shifting, scaling and rotation). As a reference a GPS-controlled stereotriplet of 1:36,000-scale aerial photographs (1990) was used. 24 evenly distributed control points were considered, which resulted in an overall planimetric accuracy of ±5 m. The pixel spacing of the digital KVR-1000 orthoimage was selected with 2.5 m, which is slightly smaller than the spatial resolution of 2.9 m of the provided data set. The ground resolution of the original KVR-1000 photographs is reported with approximately 0.7 m (Marek & Weigelt 1993).

Since the exact acquisition time of the KVR-1000 image was not available from the Russian authorities, it has been estimated by means of astronomy using shadow information obtained from the orthoimage and ephemeries of the sun. An elevation-azimuth plot of the sun for the day of acquisition (Kaufmann, V. & Fastner 1995, Fig. 10) reveals that the photograph was acquired early in the morning at 07h23m GMT, exactly one hour after sunrise.

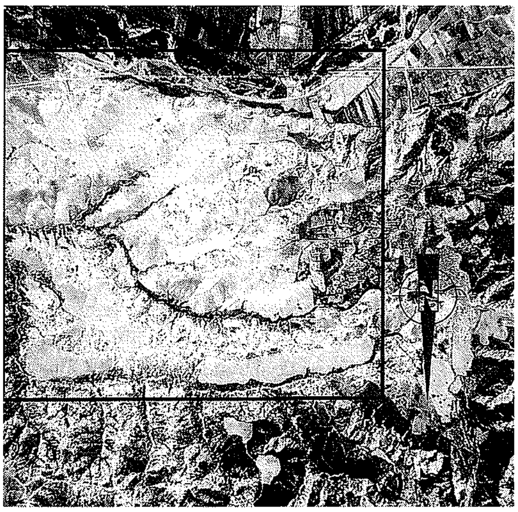
6 REMARKS ON THE GEOMORPHOLOGICAL MAPS

The Geomorphological Base Map at 1:50,000 scale and the Geomorphological Study Map at 1:10,000 scale cover an area of 126.5 km² and 5.625 km², respectively. The second map shows a subset of the first one.

Due to the very low sun elevation at the time of acquisition of the satellite image long shadows can be seen in the image maps. However, the badland forms, especially biancane, which are restricted more or less to the southward facing slopes, are strongly emphasized by the illumination of the sun. It is well known to photo interpreters, e.g. geologists or archaeologists, that a low sun elevation may reveal micro-relief features of the earth surface which cannot be identified, e.g., in aerial photographs taken at the time of culmination of the sun. In fact, the above-mentioned aerial photographs taken in the some year as the satellite image in July at 12h40m local time are not very suitable as a basis for our proposed cartographic representation because the badland areas are shown as homogeneous bright areas without significant texture due to the overall high albedo (Figure 5).

In order to get a proper relief impression the image maps have been oriented with the north direction pointing towards the observer. The 1:10,000-scale map is a thematic map which shows earth cones in red-colored circles and piping gullies in blue-colored circles, both photogrammetrically derived from aerial photographs dating from 1976 superimposed on the orthoimage. Kaufmann, K.-U. & Buchroithner (1994) denote this type of map as a combined image-line map (CIL-Map). Change detection has already been mentioned in Section 4, but map up-dating is also feasible with this type of high-resolution imagery from space. Practical work has been carried out using two different software packages, i.e. V/IMAGE from Hitachi Software Engineering and CAD-Overlay GSX from Imaging Systems Technology, with which the satellite image could be viewed at inside AutoCAD. Results of the map up-dating shall be reported elsewhere.

Image processing of the digital satellite image was done on a VAX-computer using GAMSAD, an in-house developed software for digital rectification, and on a personal computer using commercially available geoinformation systems, e.g. IDRISI and ILWIS. Image data in TIFF and vector data in DXF, respectively, were imported in CorelDRAW Version 4, where the final layout of both maps was designed. The image data were screened with 60 lp/cm for printing.



☐ = area covered by the Geomorphological Study Map 1:10,000

Figure 5. Digital orthophoto of the study area derived from aerial photographs dating from 1990.

7 CONCLUSIONS

In this paper we presented an environmental study on a badland area in Southern Italy based on a Russian high-resolution KVR-1000 satellite image. Referring to the analysis of this paper, we conclude that

- The maps are good documents of the present state of surface evolution in a subtropical badland region. As has been shown for the period 1976-1990 the maps also provide the basis for observing future environmental changes.
- This unique satellite image was found an ideal source of information for the proposed task. Nevertheless, this image cannot be used for a complete topographic mapping of the whole area due to the large amount of shadows. A more suitable time of acquisition would probably overcome this drawback. Finally, KVR-1000 images or any other images of this kind may be an alternative to conventional aerial photographs for two-dimensional mapping (mono-plotting) at scales up to 10,000. But still there remain questions about availability of data, image

geometry and quality, and costs, especially for the Russian satellite images.

8 ACKNOWLEDGEMENTS

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