REMOTE SENSING MONITORING OF OPEN - CAST MINE

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ABSTRACT: A number of remote sensing techniques such as color, panchromatic, near-infrared and multispectral photography as well as thermal infrared and video recording have been successfully tested in the lignite open-cast mine. As the result the methodology for geological mapping of slopes and toxic soils detection has been developed. Geological interpretation of such images, is carried out with reference to a set of diagnostic features, the most important of which include texture of photographic image, shape, form and structural-sedimentary elements of sediments. Information of spectral characteristics of individual lithological types of soils is also important especially for planning remote sensing registrations of slopes. Near/thermal infrared images are also of equal use in geological interpretation and monitoring connected with checking of indirect stability conditions of slopes and discrimination of lignite layers. Remote sensing monitoring of the dumping area seems to be full of promise for reclamation practice showing possibilities of thermal detecting of sour-toxic grounds as well as using airborne-photography and video recording for reclamation inventory purposes.

KEY WORDS: Remote Sensing Application, Image Interpretation, Mapping, Multispectral, Non-renewable Resources.

INTRODUCTION

The modern technology and mining engineering, including the development and improvement of geotechnology methods, make possible the exploitation by open-cast system of deposits of solid material product lying at relatively high depth - even about several hundred meters.

In the general balance of emerged minerals in Poland using open-cast system, the special place is occupied by brown coal, which exploitation, mainly for domestic energy production, takes place in several coal fields.

The first working of new deposits and particularly a large size open-cast building creates big problems for maintenance service; problems not solved till now.

The exploitation on a large scale causes not only mining and technological complications but produces the necessity of solving of many geological, engineering and hydrogeological problems and also questions connected with planning and land reclamation leading. The above designed problems extort the necessity of investigation and implementation to employment of new methods improving the work of geological mine service. Particularly useful are remote sensing monitoring methods, which considering the velocity and objective capacity of presentations and the expansion of the measuring range out of the visible region, on the essential way enrich the cognitive quality of this type of documentation. (Gebhardt, 1981, Mularz 1981, 1985, 1987, Sitek 1988). The selected aspects of investigations on using of remote sensing methods for the needs of open-cast mine geological service are discussed in this paper.

1. GEOLOGICAL MAPPING OF OVERBURDEN - SLOPES.

A study area (Liquite Open-Cast Mine „Bełchatów") is located in the central part of Poland approximately 150 km southwest from Warsaw. A size of the open - pitmine at the first working phase was about 2.5 km wide by 6.0 km long and about 250 m in deep (Fig.1).

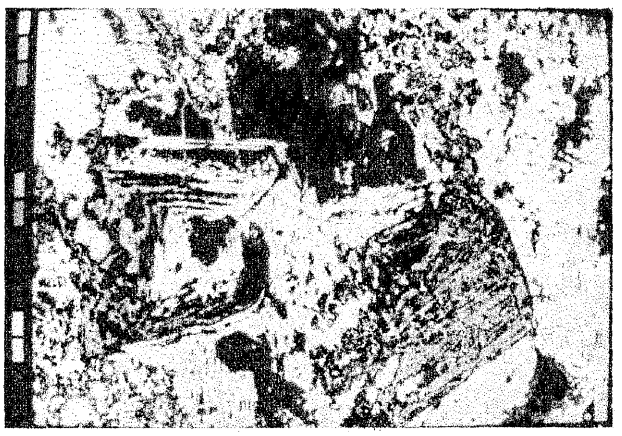


Fig.1. Portion of the SPOT image over study area Open - Cast Mine „Bełchatów", Poland). Geometry of the open pit mine and the dump body is clearly visible.

In the case of such a large open-cast mines, it is mining a lot of overburden slopes and within the deposit series, during one month, which should be mapped without delay.

This fact entirely motivates using a remote sensing methods to these purpose, making possible the fast and objective documentation of geological structure of the deposits likewise the phenomena and en-

gineering-geological processes attendant the exploitation.

The result of several years experimental investigations is the methodology of geological mapping of overburden and deposit slopes on the basis of ground and aerial photographs (Mularz - 1981). The essence of elaborated methodology bases on the following assumptions:

- the recording of slopes is made on black and white photographs (panchromatic, orthochromatic or multispectral),
- the geological interpretation of photographs is made on the basis of special version of photo-interpretation key,
- the elaboration of photographs can have analogous or numerical form and the results may be presented in the different way,
- the influence of season and weatheral conditions and the another external factors on the interpretation way of photographs is defined.

The idea of the photo-interpretation key is based on the full set of the diagnosic features, as: tone differences shape and occupation way, texture of photographs and spectral characteristic of particular types and lithological modifications of formations, creating the slop. The specificity of different formation series images is dependent of petrographical and structural features on the one hand; and the mining technology as well as the processes taking place on the slope surface after its formation by excavator, on the other hand (Fig.2) For a particular mining field, this seperate keys for discrimination of the lithological types and kind of grounds must be prepared. Such photointerpretation keys are helpful in rapid and accurate identification of geological series from photographic images.

The spectral response character of different types of grounds indicates on general accordance, it indicates namely on the reflecting power growth of the radiation, since ultraviolet to near infrared radiation with local oscillations, notable in the green part of the spectrum. The values of reflection coefficients for dry air in the entire range of visible spectrum higher than in the case of natural moisture content. It is interesting, the distinct enlargement of differences between the values of these coefficients from blue toward the red range of visible spectrum is observed. The increase of spectral reflection coefficient values is different for respective types of lithological grounds, and in this way the contrast on images is higher. For better results of geological interpretation the photograph should be taken several days after exposure on the air. If the time of slope exposure after the excavation is too long, some effects of disturbance might occur, because of drying and weathering phenomena, and therefore image is not useful for interpretation purposes.

On the basis of geological interpretation of black and white photographs, it is possible to distinguish the main types and lithological modification, exposed on slope surface of such formations, as sand, gravel, boulder clay, silt, etc. On the other hand the features enabling for the univocal interpretation of particular ground type within the given lithological modification are not visible on the photographs.

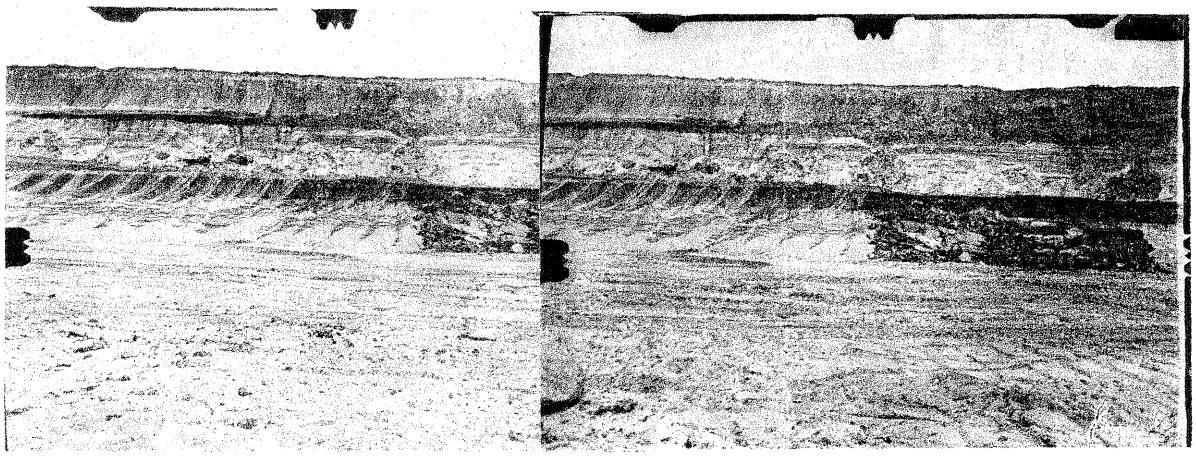


Fig.2. Stereogram showing a fragment of a typical cut slope of the overburden part of a the Liquite Open Cast-Mine.

The results of photogrammetric registration may be presented in the form of strip mine orthophotomap determining the synthesis of the photograph image and map contents. In the other words this document is fully cartometrical (Fig.3).

The orthophotomap contains also the geological interpretation results in the form of appropriate symbols or the key code set. The orhophotomaps

may be made in the projection on the vertical plane, parallel to dump profile, or on the other vertical plane, oriented eg. according to the geodetical coordinate system of the mine.

The interpretation is made mainly on the basis of different tone and the image structure occurring in the formation profile. In the case, when two formations have comparble reflectance to the coal

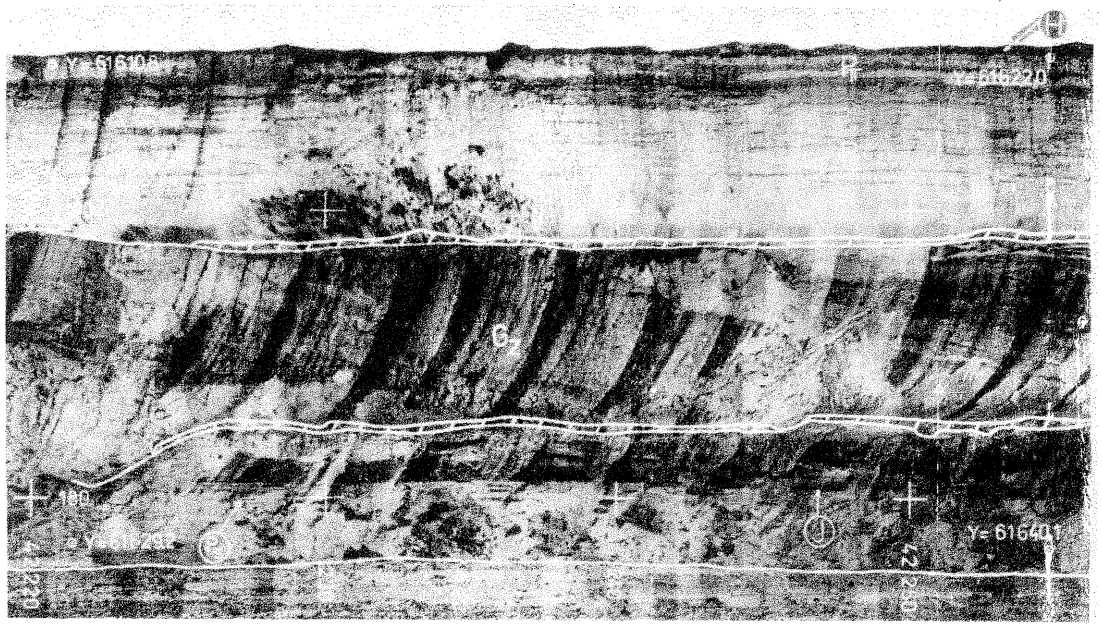


Fig.3. Orthophotomap of an overburden - slope, presented at vertical plane with geological interpretation; P, P - sands, G - boulder clay; M - silt, I - varved clay, H - humus.
Shadowed area indicate the zones masked by the slope relief and therefore is invisible from camera station. The orthophotomap was made in the vertical projection plane.

The results of the geological interpretation can be also coded in the numerical form. This form of ground photogrammetric photographs elaboration enables the utilization of their geological contents to the automatic data processing within the actualization of the geological data bank for the given deposit

2. REMOTE SENSING AND PETROGRAPHICAL VALORIZATION OF THE DEPOSIT

The documentation of geological deposit conditions by remote sensing was considering in two aspects:

- the possibility and the range of remote detection of coal and non-coal formations, generally occurred in the roof of deposit,
- the possibility and the discrimination range of the petrographical coal slope composition.

The results of investigations indicate on the uniform identification of coal being among deposit formations, consisted of the sand groups with differentiated colour from the brown to white-grey tint, or consisted of loam formations with variable colour from different brown tints to almost black colour, or consisted of interbeddings, generally in white or in the creme-grey tint.

in the visible range of spectrum and also the comparable macroscopic features (eg.coal clay) - the recognizing them on the panchromatic photograps may be very difficult or even impossible (Fig.4).

On the other hand formations of this type are very good discriminated on the near infrared images, although the main part play here the differences in moisture content at surface layer of these two formations.

The interpretation of coal bed panchromatic photographs allows for petrographic recognizing of its petrographical features. It appears that at the some time it is possible to recognize some lithotypes groups, namely: smudge coal and xyloid coal. Among the lithotypes groups it is possible to distinguish: smudge coal, bituminous smudge coal, and among xyloid coal group it is possible to distinguish: structural xyloid coal and fragile xyloid coal.

The recognition of geological-deposit features has an essential significance for selective mining of coal slope, whose purpose is on the one hand the separation of the useful components from another formations, and on the other hand - the initial segregation of raw material having different technological parameters.

a)

b)

c)

d)

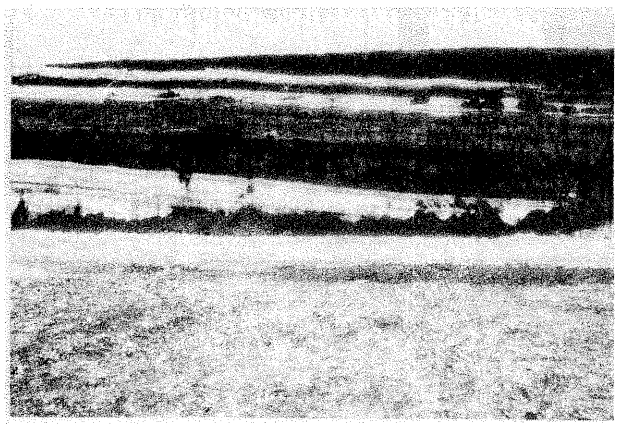


Fig.4. Sequence of multispectral photographs showing the upper part of the lignite deposit. Lignite layers are interbedded by coal - clay and gyttja and are easily recognized on the infrared band only. a)photograph taken without filter (panchromatic mode); b)green band; c)red band; d)IR band.

3. THERMAL SLOPE MONITORING.

The concept of infrared mapping slope monitoring is based of the results of ground observations and laboratory testes. According with obtained results the thermovision may by use:

- to the sensing of water signs, first of all within permanent slopes of strip mine,
- to the localization of toxic soil within the dumping ground and to the control of their neutralization.

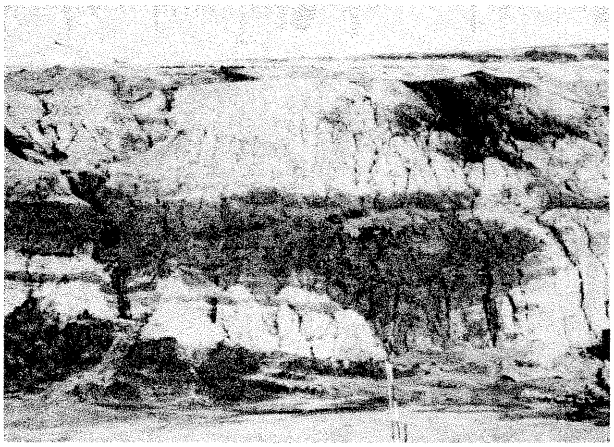
The detection of presence of water within permanent slopes of the dumping ground (in the form of outflow, effusion or the higher moisture zones) is very important element having influence on the evaluation of dump stability conditions, and on the work of drainage system in the mine.

The method of thermovision slope monitoring bases on occurrence of different temperatures between wet and relatively dry ground. Generally observed thermal anomaly are caused by real temperature differences, although frequently the great significance for projection of thermal ground-water conditions has the emissivity factor. It is satisfied that the clear dependence of the emission coefficient on the water saturation degree of ground, for the some temperature level (Blanchard et al, 1974, Ellyett et al, 1979; Mularz et al, 1984).

The best feature for interpretation of water level in the slope have the thermograms made in the early morning, before the sunrise, during the maximum ground chilling. In some meteorogical situations good results are also obtained on thermograms made during the day time (Fig.5).

The advisability of remote sensing thermal techniques to investigation of dump formation is motivated by necessity of full diagnostic of ground character for land reclamation. The reconstruction of the active soil layer on the ground, consisted of different

a)



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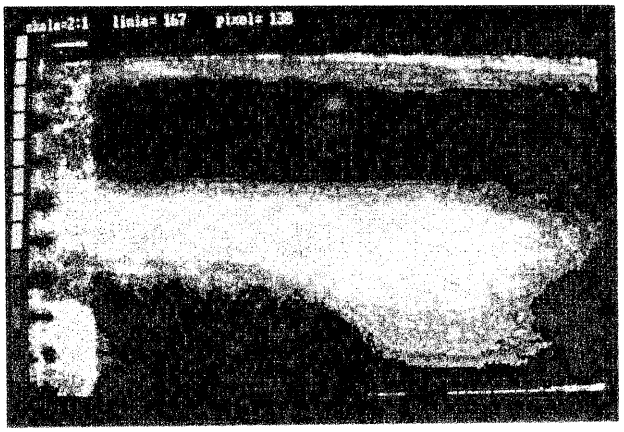

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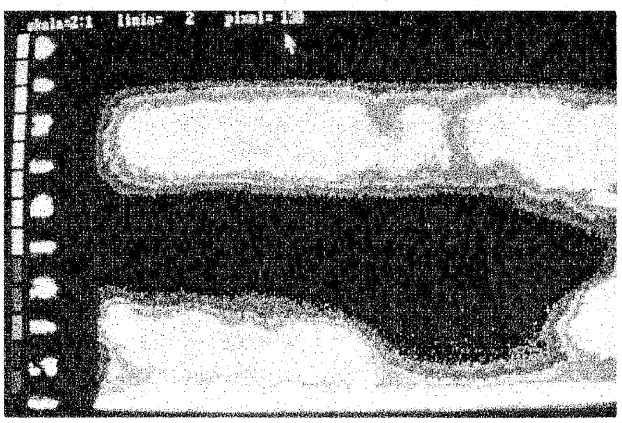

Fig.5. Black and white photo (a), and thermal images of an overburden-slope. Water content zone is clearly visible on „daily thermal image" (b) and also after digital image processing as a thermal inertia effect (c).

overlay formations, is very complex process and requires a neutral reaction of soil. The soil having too small pH values are designed as the toxic, acid ground. These grounds demand an initial neutralization before introduction of flora. In the other words, the localization of these formation is very essential for proper projection and leading of land reclamation works. Thermovision survey is extremely useful for toxic soil detection an the waste-dump slops.

It was stated, that the toxic ground are characterized by high level of radiation temperature, which many times exceeds the emission of neighbouring formations (Mularz, 1987).

The character and the projection way of the toxic ground is almost identical on the evening thermograms, taken directly after sunset, and on the sunrise thermograms, recorded in minimal thermal contrast conditions. It is very important, that this fact is not the effect of real temperature distribution, but it is caused by differences in emission ability of toxic and background soil.

In the course of laboratory investigation, it was stated, that the sample of toxic soil after neutralization by destilated and ammonia water characterize of considerable reduction of thermal radiation in comparison with active state.

Practical aspect of executed researches consist in possibility of practical application of the remote thermal recording, made first of all from plane, in order to description and control of toxic soil neutralization on the dumping groubd area.

4. COMPLEX ESTIMATION OF GEOLOGICAL CONDITIONS.

Aerial photography taken periodically over the open pit mine area, allow for complex estimation of geological conditions; generally in the sphere of:

1. recognition and documentation of geological conditions, and notable in discrimination of lithological character of exposured formation on slopes and working levels, within the overlay and deposit series (Fig.6),

2. ground lithological character recognition within stable slopes and the top of dumpbody for the necessity of land reclamation design.

3. interpretation of the engineering-geological processes, occurring at open pit mine slopes, foreground, slopes and the top of dumpbody (slope deformation of landslide type, erosion, base displacement etc.) for necessity of engineering-geological prognosis (Fig.7 and 8).

4. inventory of exploitation works and balance of mineral output effects for estimation of resources utilization,

5. efficiency control of land reclamation works,

6. definition of mining-exploitation conditions and notable the position and work of technological sequence, description of excavation and dumping ground geometry, the state of working levels, localization and work of particularly elements of drainage system, etc.

Fig.6. Aerial viev of overburden-slops and working plane of the liquite open pit mine. Sandy - clay ground - massif dissected by water-content zones is masked by mining operation features.

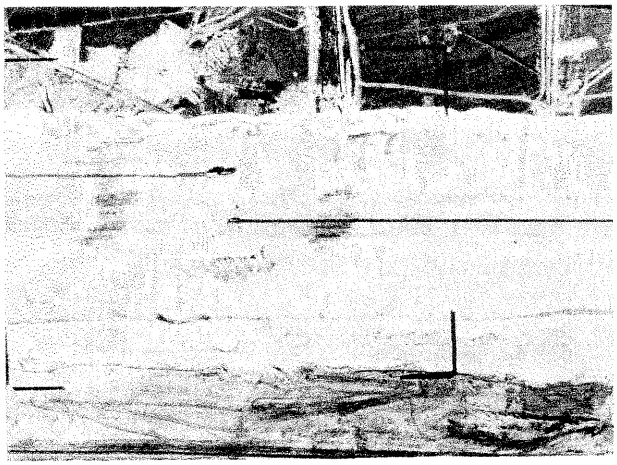

Fig.7. Water outflows as a slope deformation symptoms recognizable on black and white aerial photograph because of high contrast and specific pattern.

Generally, photographs are made in every half year, using the scale from 1:5000 to 1:8000. The ortho-photomaps are notable useful form of photogeological elaboration of plane images for the necessity of mine geological service. Orthophotomaps allow not only on qualitative estimation of interpreted phenomena and processes, but also on quantitative description.

As a rule, the possibility of uniform interpretation of geological features exist with reference to main litho-logical and structural elements. Engineering-geological phenomena and processes are readable and all slope deformation symptoms are easily recognizable.

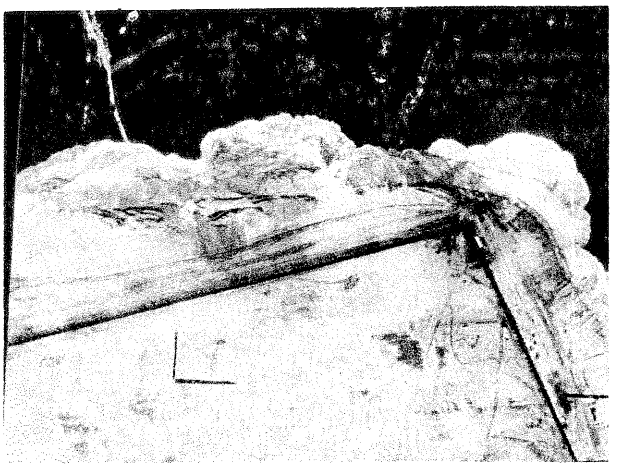

Fig.8. Deformations of a dump slopes caused by toe-failure process. Upliftings and landslides zone is visible round the corner of the dump body.

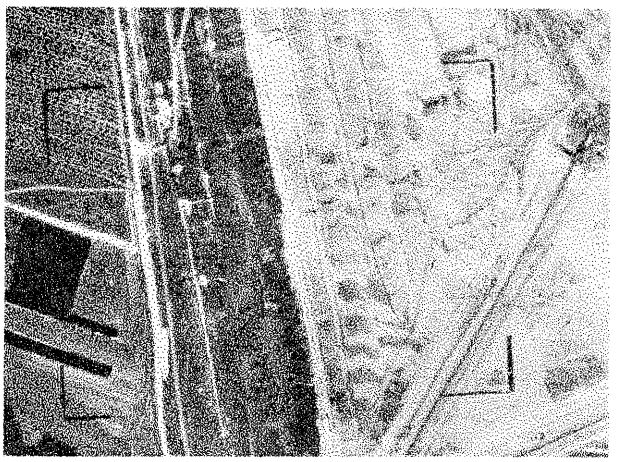

Fig.9. Aerial viev along the slope of the dump, about 300 m in height. (each step is 30 m in height). Effects of the reclamation activity are visible at the lower part of the dump and also an erosion symptom is easy to recoquize.

The stereoscopy observation allows for landslide geometry definition, its morphological and structural elements, and also for estimation of moving mass volume. Aerial image enables moreover the examination of rising form in the more wide context of geological slope structure, water conditions, etc.

The projection of images of elements serving to the evaluation of land reclamation efficiency, realized on stable slopes as well the strip mine as the dumping ground is satisfied.

CONCLUSION

The remote sensing methods using for the geological service of open-cast mines are notable useful and desired. The results of realized experiments indicate, that remote technic may be successfully applied to solve so principal problems as actual mapping of overlaid slopes specification and evaluation of geological-deposit conditions, recognition and con-

trol of engineering-geological processes, and also the geological preparations to land reclamation works.

The remote sensing methods eliminate in great part the subjective factor and allow for the work efficiency increase of the geological service, what has the fundamental significance for mining work, especially in the large space open-cast mines.

REFERENCES

Blauchard M.B., Greeley R., Goettelman R., 1974. *Use of visible, near infrared, and thermal infrared sensing to study soil moisture*, NASA Techn.Mem.X-62, 343, 8p.

Bowers S.A., Hanks R.J., 1965. *Reflection of radiant energy from soils.* Soil Sci.100.pp.130-138.

Ellyett C.D., Pratt D.A., 1979. *The Thermal Inertia Approach to Mapping of soil Moisture and Geology.* Remote Sensing of Environ, 8 pp.151 -168.

Gebhardt A., 1981. *Spezielle Möglichkeiten des Einsatzes abbildender Infrarot - Messverfahren bei der Erkundung Abbau von Braunkohlenlagerstätten.* Neue Bergbautechnik, No 6. pp.319 - 322.

Idso S.B., Schmmugge T.J., Jackson R.D., Reginato R.J., 1975. *The utility of surface temperature measurements of remote sensing of surface soil water status,* J.Geophys.Res. 80(21). pp.3040-3049.

Mularz S., 1973. *Toe-failure processes on an opencast mine waste-dump.* Studia Geotechnica, Vol.IV, No 1 pp.23 - 34.

Mularz S., 1981. *Geological mapping of escarpments in opencast mine on the basis of photogrammetry.* (In Polish). Przegląd Geodezyjny No 4. pp 169 -173.

Mularz S., Tokarczyk A., Tokarczyk R., 1984. *Thermovision applied for investigation of a cut slope of a large lignite open pit.* (in Polish). Zeszyty Naukowe AGH, No 998, Geodezja z.84. pp.169 - 182.

Mularz S., 1985. *Thermovision Observations of the slopes in a strip mine.* (in polish). Fotointerpretacja w Geografii Vol.VIII (18). pp.104 - 112.

Mularz S., 1987. *Thermovision investigation of dump soils.* (in polish). Ochrona Terenów Górniczych No 80/2.pp.36-44.

Mularz S., 1989. *Thermal monitoring of a slope for geotechnical purposes.* Procc. of 6-th Conf. on Thermogrammetry and Thermal Engineering, Budapest. pp.191-194.

Sitek Z., 1988. *Slope monitoring in open cast mines using close range remote sensing method.* Procc. of the Indo-British Workshop on „Remote Sensing of Environment in Mining Field", pp.99 - 107.