

GUIDELINES FOR SAND DUNES MAPPING

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SUMMARY

The paper presents remarks concerning mapping of sand dunes appearing in sand desert areas. According to authors opinion the sand dunes should be treated both as relief forms and as planimetric details. In consequence, the sand dunes should constitute the relief as well as the planimetric contents of topographical maps. In addition to the contour lines and spot heights the planimetric position should be depicted by lines indicating the crest lines and dune outline. The mapping guidelines are related to the different forms and patterns of sand dunes.

1. GENERAL REMARKS

Sand desert areas appearing on different continents constitute about 20% of land areas of our globe. At the beginning of cartographic activity in such areas, the sand desert areas were disconnected from standard or classical topographical mapping and were presented on topographical maps only in a very simple and approximate way. On topographical maps at small scales only the main trends of dunes were depicted and areas covered by sand dunes were marked by conventional symbols. During sand desert expeditions the explorers prepared sketches rather than maps along their itineraries (Bagnold, 1933).

The application of aerial photographs and in the recent years of satellite images created the possibilities of mapping such vast and remote areas. Hence, the problem of mapping. How such areas and the sand dune forms appearing in desert areas have to be presented on topographical as well on thematical maps ?

2. SAND DUNES AS ELEMENT OF TERRAIN TOPOGRAPHY

In sand desert areas, such as the great sand seas in North Africa or in Saudi Arabia, the sand dunes constitute the only element of terrain topography. The sand dunes represent the variety of forms and patterns (Linsenbart, 1987c), which are characteristic for different sand seas and sometimes changing within particular sand seas. The dimensions of sand dunes vary both in planimetry and in elevation, and together with dune forms and patterns are function of sand origin, climatic changes, wind regime and topography of basement and surrounding areas. Generally, the sand dune forms, taking into consideration their elevations can be divided into three groups : ripples - the smallest forms with heights in centimetres, sand dunes - with elevation from several up to 20 or 30 metres and sand ridges with relative height up to 200 m and occasionally up to 300 m (Wilson, 1973).

Ripples, which constitute the smallest form in sand forms family, are generally excepted from topographical mapping and can be measured by special classical or photogrammetric technics.

For topographical mapping the most important are the sand dunes and sand ridges. The sand dunes can be classified into three groups: simple forms, composite forms and compound forms (Linsenbarth, 1987b). The simple forms represent the elementary dunes such as barchans, crescentic dunes, linear dunes and star dunes and appear mostly on the margin of sand seas or as secondary forms in so called compound forms. The composite forms constitute the composition of simple forms arranged at the same level. These compositions should be created by the same simple forms such as composite linear dunes arranged in the bundle of linear dunes with largest principal linear dune and attached smaller linear dunes forming feathered forms. Composition of crescentic dunes results in so called crescentic chains and composition of barchans results in barchan chains. Combination of two different forms, can be presented by composition of linear dune with barchan, resulting in so called hooked dune.

From the point of view of terrain topography the most important are the compound forms consisting of two dune forms superimposed one onto another. These forms constitute the main parts of sand seas. The lower level of compound form is created by sand ridges, constituting so called primary forms (Linsenbarth, 1987b), and the upper level consists of simple or composite forms of sand dunes superimposed onto primary forms. These two components of compound forms can be distinguished by their dimensions - the primary forms constitute the largest sand bodies with the elevation up to 200 or even 300 m, while the secondary forms are rather small up to several metres in height. There are different types of compound forms, but the most common forms belong the longitudinal sandridges up to 2 or 3 km in width and up to several tens of kilometres in length. To the secondary forms superimposed on the longitudinal sandridges belong linear dunes or chains of crescentic dunes arranged generally on one side of sandridge and star dunes on the top of sandridges. The other very common forms appearing in Libyan and in Algerian sand seas are domical sandridges, creating sand hills or large star dunes forming the largest sand bodies. The diameter of domical sandridges and star dunes is up to 3 km (Linsenbarth, 1987c).

In sand seas the dune forms appear in a very distinct patterns creating sand seas topography. The longitudinal sandridges are commonly arranged in a set of parallel trending ridges or in a grid pattern created by two dune trends. The star dunes or domical ridges can be arranged in chain pattern or in random pattern. Generally each particular sand sea has its own pattern of dunes but sometimes the similar patterns are repeated in other sand seas.

In sand dune patterns beside the sand dunes or sandridges it also appear the interdune areas or corridors, which constitute a very important element in sand areas topography. The interdune corridors are generally very flat and are covered by very thin sand sheets without dune forms. Occasionally only ripples appear in interdune corridors. The interdune corridors vary in width from several hundred of metres up to two or three kilometres. In the grid pattern the interdune areas resemble the closed figures - circular, elliptical or diamond-shaped.

A very important and also very controversial problem in the topography of sand areas is the question of stability or mobility of sand dune forms. Very popular is the opinion that the sand dunes are very mobile and can not be treated as unchanged terrain topography. This point of view is based on the analysis of small simple dune forms such as barchans, which belong to the most mobile dune bodies and sometimes are called the sand transport vehicles (Mainguet,1984). On the other hand studies performed by many authors in recent years (Warren,1970, Wilson,1973 Linsenbarth,1987) indicated that large dune forms so called sandridges (or draa), which appear in sand seas, belong to stabile forms. Wilson(1972) on the basis of performed studies concluded that the migration rate of sandridges is 5.4 cm per annum. Generally it can be stated that in compound forms the primary forms are unmobile while the secondary forms, superimposed on primary forms, can be accounted to mobile forms. Hence the main bodies appearing in sand seas should be treated as the stabile element of terrain topography.

3.SOME ASPECTS OF SAND DUNES MAPPING

As it was stated, the sand dunes constitute the terrain topography, so they should be presented on topographical maps as well as on the other thematical maps such as geomorphological or geological maps. The analysis od different maps covering North African sand seas, performed by the author of this paper, indicated that generally sand dunes are presented improperly. The sand dunes are treated solely as relief elements, hence their presentation depends on the contour interval and on the number and location of spot heights. In such case the proper presentation of dune forms is a function of the relative dune height and contour interval. From the classical topography it is very well known that the terrain forms should be presented as a minimum by two or three contour lines, but in the case of more complicated terrain forms, the number of contour lines should be much bigger. If this condition can not be fullfilled, than the terrain forms, in our case sand dunes, will be presented by one contour line related to the selected level of dune, thus not showing the proper shape and dimensions of a sand dune.

The proper presentation of sand dunes by contour lines will only be effected when the bottom, slopes and top of the dunes are depicted by contour lines and spot heights. This condition is very difficult especially for small-scale mapping when the contour interval is limited by the scale of aerial photographs. According to the sugestions given by the author of this paper (Linsenbarth,1987b) the sand dunes should be treated both as element of terrain topography and as the element of terrain planimetry. The outline of the dune base and the dune crest lines can be treated as planimetric details and as such elements depicted on maps. In such a case the contour lines and spot heights will give only the supplementary information related to the dune elevation.

In case of simple or composite forms the proper and very detailed presentation of crest lines and dune outline is very important for futher geomorphological studies. The relation of dune crest to the dune outline gives information on dune symmetry or asymmetry(Mabbutt,1977). The height information should be related both to the crest line and to the dune outline. It should be

noted that in a case of linear dunes, the crest lines change their heights due to the appearing crestal saddles and summits. Sometimes the crest appear in multiple or braided forms. In many cases the sand dune outline appear at different elevations a fact which should be taken into consideration in photogrammetric plotting procedure.

The sandridges, comprising the primary and secondary forms, should be mapped very carefully thus allowing proper interpretation of dune forms on maps. The primary forms represented by large longitudinal or barchanic sandridges or by huge star or domical dunes, have to be depicted mainly by contour lines and by spot heights, and if necessary, by lines indicating the outline of dune base and the dune top. In case of star dunes, all arms radiating from the dune top should be depicted. All crest lines should be plotted in great detail thus allowing the reversing dune forms and other forms to be differentiated.

The secondary forms, represented by simple and rather small dune forms, should be depicted as planimetric elements. Due to small dimensions of these secondary forms, only the crest lines of those forms should be plotted. It should be noted that generally the secondary forms appear along one side of longitudinal sandridges and are created by current winds.

Sometimes, the interdune areas are covered by giant sand ripples. The crest lines of those ripples have to be plotted on maps.

The level of interdune areas or corridors has to be indicated by spot heights. In desert areas beside the present dune forms, also the relict subdued dune forms can be detected and traced on aerial or satellite photographs and than presented on the maps (mainly on thematical maps) by special symbols.

The maps plotted in the above mentioned way will supply much more information for future, more detailed geomorphological studies of dune forms and their relation to sand origin, terrain topography, wind regime and for studies of sand dune development.

4. CONCLUSIONS

The topographic maps of sand desert areas constitute the basic maps for geomorphological or geological mapping, so their should contain all the information on terrain forms . These information will be very usefull for more detailed thematic studies. In sand desert areas the sand dunes create the only element of terrain topography and the solely element of the map contents.

The mapping of sand desert areas should be preceded by detailed geomorphological studies of dune forms and patterns appearing in the mapped area. For such studies satellite or high altitude photographs can be applied. On the basis of performed studies the technical specifications for photogrammetric plotting and cartographic mapping should be worked out. In such specifications, the most convenient contour interval should be selected and the guidelines for planimetric plotting of dune forms and patterns should be given.

In case when orthophotomaps are prepared for sand desert areas, the terrain image should be supplemented by elevation information (contour lines and spot heights). For colour photomaps

or mosaics prepared on the basis of satellite images, such enhancement should be applied during image processing that even small changes in dune colour could be noted. Those sand colour changes are correlated with sand grain size, sand origin and sand transport.

5. REFERENCES

- Bagnold, R.A., 1933 : A further journey through the Libyan Desert, Geogr. Journal 82, 103-129.
- Linsenbarth, A., 1987a : Application of Metric Camera space photographs for geomorphological studies of sand desert in Libya, International Scientific Colloquium: Use of space photographic data for mapping of Earth surface, Leipzig, 4-5 Sep. 1987.
- Linsenbarth, A., 1987b : Sand seas mapping - remote sensing approach, Willi Nordberg Symposium 1987 - Remote Sensing : Towards operational cartographic application, Graz-Austria- Sep. 7-9, 1987
- Linsenbarth, A., 1987c : Sand desert forms in Libya- remote sensing analysis. Third Symposium on the geology of Libya, Tripoli, 27-30 Sep. 1987
- Mabbutt, J.A., 1977 : Desert landforms, The Mitt Press, 340 p.
- Manguet, M., 1984 : A classification of dunes based on aeolian dynamics and the sand budget, in: Deserts in arid lands (ed. Farouk El Baz) Martinus Nijhof Publishers.
- Warren, A., 1970 : Dune trends and their implications in the Central Sudan, Z. Geomorph. Suppl. 10, 154-180.
- Wilson, J.G., 1972 : Aeolian bedforms - their development and origin, Sedimentology, 19, 173-210
- Wilson, J.G., 1973 : Ergs, Sedimentary geology, 10, 77-106.