

Presented Papier

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The visual interpretation of colour synthesis images

Abstract

The great detail information density of colour, false colour and especially multispectral images for the remote sensing of earth resources from cosmos or from great flying heights calls for an appropriate image processing for the purpose of interpretation.

One of these processing methods is the production of colour synthesis images, in which up to 100 times more colour tones are discernible than grey values in the original black and white photographs.

Interpretations of colour synthesis images are inter alia presented whose original photographs taken with MKF 6-Soyuz, MCC-Skylab and MSS-Landsat were subjected to the purely analogous but also to the digital-analogue colour synthesis.

(The colour synthesis images are distributed as colour prints to interested persons at the ISP Congress)

## 1. Task and solution

Because of the large information content of multichannel multispectral photographs they can generally be utilised for several geoscientific applications simultaneously. It is, however, reasonable to use only one specific interrogation mechanism for each individual geoscientific task. Finding the appropriate mechanism is the task of the interpretation technique. Normally the technique starts from reference objects. In the interpretation of photographs e.g. from the orbit these reference objects have to be checked at least by a second method - normally by an aerial photograph and/or ground observations. The interpretation key for this can be supplied by visual interpretation.

The visual interpretation of multispectral photographs and their colour image syntheses will also generally be applied in cases, where statical problems are to be investigated with the aim of exploring a specific situation, as e.g. in the Raduga experiment (Soyuz 22) the exploration of regions with soil salinization in northern Kazakhstan or the formation of tectonic structures in the shelf zone of the GDR. On the other hand, the visual interpretation in multispectral investigations of dynamic processes will be applied only in the test phase of the automatic instrumental image interpretation.

For improving recognisability and visual interpretation useful tools are:

- A) Binocular magnifying instruments such as interpretation stereoscopes (Fig. 1 - Interpretoskop from JENA) and microscopes for three and two-dimensional observation with zoom optics and high image magnification (up to 100 times) for black-and-white multispectral images and multispectral colour synthesis images /2/.

This applies especially to photographs which with photo-optical camera systems achieve resolutions up to 160 l/mm, as e.g. the photographs of the MKF 6 Multispectral Camera /7/.

- B) Magnifying projection instruments for the interpretation of black-and-white information by means of normal projection and for the interpretation of spectral information by means of multichannel colour synthesis projectors (Fig. 2 - MSP 4 Multispectral Projector from Jena) /6/.

So, for visual interpretation two instrument groups have been made available, which enjoy equal rights in their place, the first group being primarily used for detail interpretation of image sections, the second primarily for the overall interpretation of the total image.

In both groups it is useful to have facilities for the photographic recording of the image.

The degree of interpretation of multispectral images is

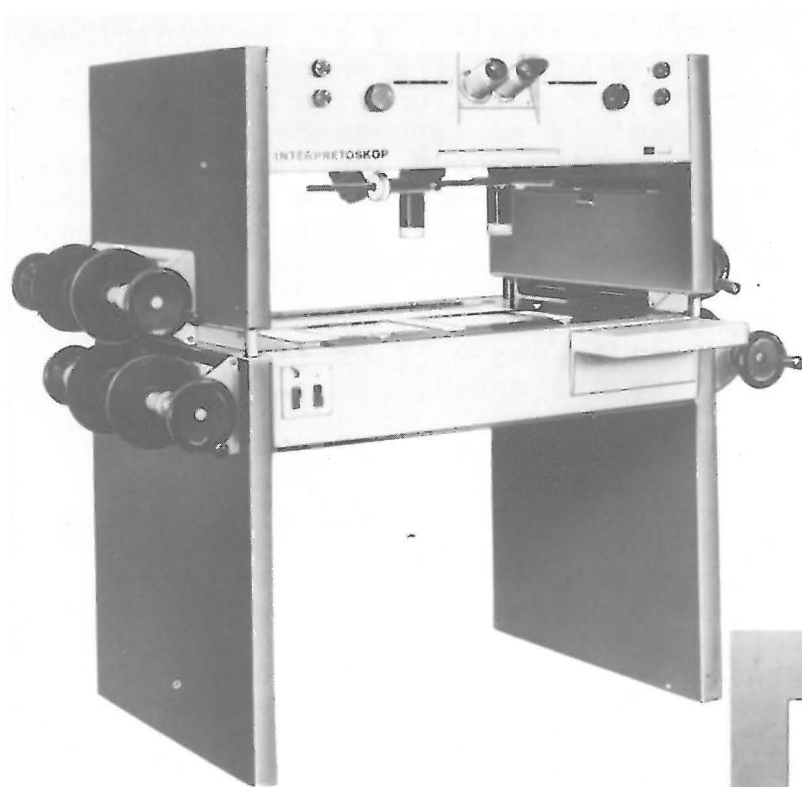


Fig. 1

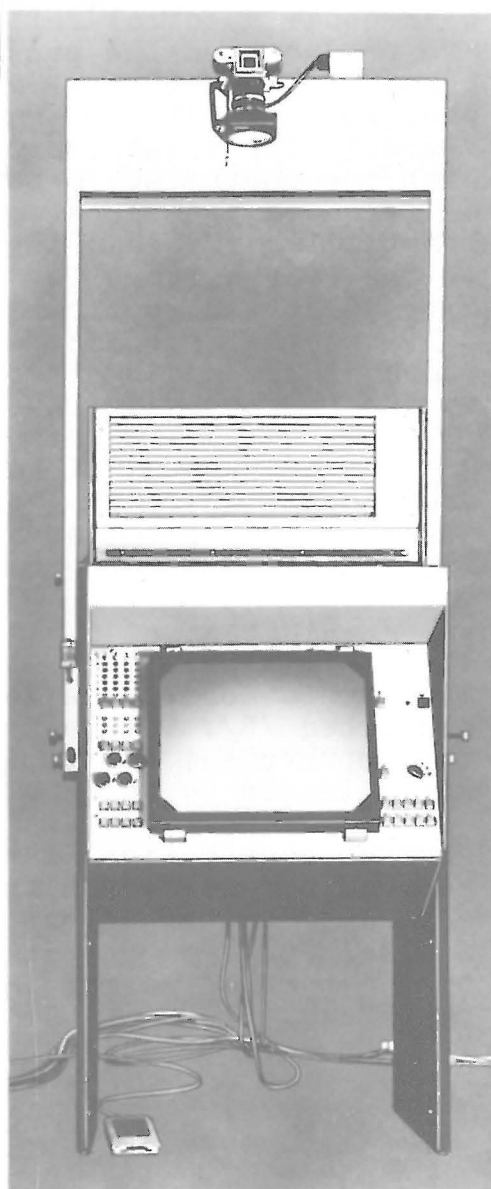


Fig. 2

characterised by the sum of the properties of the individual image determining the quantity of details which can be obtained by interpretation for the solution of a concrete interpretation task. Here, the fact is of importance that the human eye is capable of discerning about 100 times more colour tones than grey values in black-and-white photographs. By means of multispectral information the expressive effect of the images can be so enhanced by synthesizing the colours that the discovery and identification of important objects and features which characterise the solution of the concrete interpretation task can visually (as well as instrumentally) be made with high reliability and speed.

Colour synthesis involves a special processing of the available information. It is accomplished by the colour mixing or multispectral projectors which optically combine the individual images of different camera channels again into one single image. The information associated with various spectral ranges is coded with different colours. For objects with equal spectral reflection properties equal image colours are produced on the projection screen of the projector. By the suitable choice of the projection light intensity and the code colour such a colour match is achieved as is most favourable for visual interpretation. It must be in accordance with the photographic recording so as to avoid, for example, differences between visual interpretation and the photographically recorded interpretation key. Hence, in addition to the code colours for visual interpretation which is adapted to the spectral sensitivity of the eye the MSP 4 Multispectral Projector has extra code colours for the photographic recording in order to avoid colour falsifications in the neighbouring layers of the photographic colour material.

Furthermore the MSP 4 has the necessary number of degrees of freedom so as to bring the images of the individual channels so exactly into registration that no loss of information in detail ensues from colour fringes /3/.

The combination of digital image processing techniques with the facilities of a multispectral projector for better visual interpretation of the colour synthesis images was already described /5/. The technique of image processing resulted in the improvement of the individual multispectral black-and-white images by means of histogram equalisation.

Another combination is possible for example in the case of poor colour differentiation of natural colour images. A considerably better colour differentiation can be achieved by digital image processing of the three colour separations of such a natural colour image and subsequent colour image synthesis.

## 2. Data and description of selected colour synthesis images

The colour synthesis images described and interpreted in the following were synthesized from multispectral photographs which were taken by different photo-optical and digital camera systems from the orbit or from the air. They were produced after analogue, digital-analogue as well as analogue-digital-analogue conversion in the MSP 4 Multispectral Projector from JENA. Although the terrain was generally unknown to the operators, the colour synthesis in connection with visual interpretation shows its great use for the exploration of our natural environment.

### 2.1. Baikal region (Soyus 22, Fig. 3)

The following interpretation is based on a set of MKF 6 photographs of the Baikal region taken by the Soviet space vehicle Soyus 22 from a height of abt. 265 km. The original pictures have an image scale of approx. 1:2,100,000. The six-channel camera from JENA records in four ranges of the visible light as well as in two photographic infrared ranges. The picture format is 56 mm x 80 mm. The alignment was readily performed by the fiducial reseau marks imaged on the photographs. High resolving power, low distortion, parallel single cameras aligned with extreme precision and the exact simultaneous exposure yield very good geometric and radiometric image resolutions. The colour synthesis was made on ORWO material. It covers a territory of abt. 115 km x 160 km.

In this colour synthesis a series of zones becomes distinctly visible by colour differences on the western Baikal bank, where depending on the age and degree of metamorphosis various rocks have formed. A zone of archaic formations with a mighty massif of gabbroites is thrown into relief on the western bank of the Baikal lake.

In the range of the rocks of archaic age it is possible with magnifications of the image to ascertain in the thin depicted channels the direction of the eluviations in the layers displayed on the photo, to clarify elements of the internal structure and to derive the complicated formation processes, which are of interest for the discovery of hydrothermal mineralisations.

The distinctly noticeable mighty fracture crossing the bank in the Buguldeyka territory is the well-known boundary, where slidings to the left occurred in the past.

The clarification of the tectonic structure leads to establishing a relation between known deposits or ore occurrences and specific structural forms and hence to the prognosis of new accumulations of mineral raw materials.

Great possibilities are opened up by the interpretation of multispectral photographs for the study of recent sedimentary processes.



In the investigation of the delta of the Selenga river imaged on cosmic photographs of different channels it was found that on each of them different contours appear which reflect different degrees of swamp formation and thus different concentrations of deposits. The precipitation of territories which were overlaid by deposits of various facies of the alluvial river and flood deposits and their demarcation from the terrace complex of the river plain are of considerable importance for the discovery and the study of deposits. When the knowledge of appropriate correlations has been acquired it will presumably be possible to draw inferences from differences in the composition of vegetation which were clearly depicted in the photograph to the differences of the lithologic composition of the rocks /1/.

## 2.2. Columbia River plains (Skylab, Fig. 4)

This picture was synthesized from sheet film positives obtained in the EREP 190 A experiment of the US Skylab space station.

The six-channel ITEK camera recorded in two ranges of the visible light, two infrared ranges as well as on one infrared false-colour film and one high-resolution Kodak colour reversal film. The format of these images is 58 mm x 58 mm. The false colour picture was synthesized in the standard variant from the channels 400 - 500 nm (blue), 500 - 600 nm (green) and 700 - 800 nm (red). Resolution is excellent throughout the entire image field with low marginal deterioration (caused by filter and objective).

During alignment it was found that the fiducial mark system of the ITEK camera exhibits considerable differences between the channels. Therefore, the alignment was made by resorting to conspicuous object contours using the attachment microscope for control. With proper registration of the images differences of the fiducial marks of up to 0.2 mm occur in the negative plane. Compared with this, distortion differences are low.

The photos were taken from a flying height of about 435 km during the US Skylab mission; they show a region that is characterised by forests, farmland and pastures as well as by the conspicuous course of the Columbia river with its numerous tributaries.

The image covers an area of about 50,000 km<sup>2</sup> under a cover of loosely scattered clouds. The region belongs to the basalt plains of the Columbia River in the state of Washington, USA. The plain is formed of Tertiary basalt rocks. It is crossed by the Columbia River from top left to bottom right and the Snake River, one of its major tributaries (at bottom, right). The Crab Creek runs parallel to the top margin. The plateau has an average level of 300 m above S.L. The gently rolling hills in the east and southeast reach heights between 400 and 600 m, whereas the dissected ridges west of Columbia River rise to between 1,000 and 2,500 m. The 2,886 m high Mt. Stuart is just outside the area covered.

One striking feature is the geometrical mosaic of tillage areas appearing in reddish-brown and yellow hues. Decomposition has turned the volcanic rock into an extremely fertile soil, on which rich harvests of grain, fruit and vegetable crops are gathered thanks to intensive artificial irrigation, such as simple flooding of fields by canals and weirs (at bottom, left) or by a central pivot sprinkling system (seen as circular reddish-brown spots, mostly east of Columbia River). The farms in the east and north appearing in various shades of green are mostly pastures.

Artificial irrigation requires large reservoirs. The picture shows the Pothole Reservoir below the bluish airport runways (above the image centre) and two barrages of the Columbia River, Wanapum Lake Reservoir and Priest Rapids Dam, east of the ridges to the left in the picture. Where artificial irrigation is missing completely, certain soil types may locally form dune areas (west and north of the almost square Moses Lake just above the image centre).

### 2.3. Columbia River Plains (Skylab, digital image processing, Fig. 5)

The natural colour image obtained from the experiment mentioned under 2.2. shows only slight colour differences and is almost a bluish-violet monochrome. To improve colour differentiation the image was subjected to digital processing.

Three colour separations of this photograph were digitally processed and in the MSP 4 recombined into a colour synthesis image. It can be seen that digitally processed images with a raster size of 100  $\mu\text{m}$  or more can be handled in the MSP 4 without any particular problems. With rasters smaller than 100  $\mu\text{m}$  it depends on the quality of the processed images, whether adequate registration can still be achieved. In contrast to analogue images where registration differences are revealed by object contours, digitally processed images require that all picture points are exactly in registration. Even a shift by only one pixel may falsify the result.

As a result of the digital-analogue procedure the various types of land use can be well discerned. Forests as well as fertile tillage areas and pastures can be distinctly demarcated from each other (compare the description of picture 4). The river courses are partly enhanced in a characteristic manner. Difficulties of interpretation arise, however, in the right image part from cloud shadows on the pasture appearing as light violet areas which may be confused with forests (e.g. left of the Columbia River).

### 2.4. Yellowstone National Park (Landsat, Fig. 6)

Diapositives at the scale 1:3,360,000 were used as starting material, whose quality was good. Disturbing scanner errors were not noticeable. Alignment in the MSP 4 Multispectral Projector is readily possible. The fiducial marks and the Landsat data are preferentially aligned under the attachment microscope so as to bring them into registration. The grey

scale in the Landsat photographs has been matched to the radiometric calibration and the Kodak colour process.

In the colour match to neutral grey of the scale equal colours for equal radiometric conditions result for the Landsat standard synthesis in all pictures. This correlation is not given, when the colours are arbitrarily matched and when colour processes with a different gradation are used. The present photograph was taken on PC 7 ORWO sheet film (40 cm x 50 cm) with the filters 5, 7 and 9 of the MSP 4 and additively contact-printed with the ORWO filter set on PM 20 colour paper. The paper was processed according to ORWO instructions. From the image scale and the constant 5x enlargement of the MSP 4 the scale of the print is obtained to be abt. 1 : 670 000.

The represented terrain section covers an area of abt. 185 x 185 km<sup>2</sup> (= abt. 34 000 km<sup>2</sup>) and shows parts of the Federal States Wyoming, Montana and Idaho with the total territory of the Yellowstone and Grand Teton National Parks.

Geographically, the photographed region is part of the central Rocky Mountains with average heights between 2,000 and 4,000 m (e.g. snow-covered summits of the Grand Teton area up to 4.196 m in the middle at bottom). In the left lower corner there extends part of the largely flat region of the Snake River Plain which in its western part falls below 1,000 m.

Conspicuous features are the deeply dark green water surfaces e.g. of the Yellowstone Lake (east of the image centre) and of numerous other lakes, all of them at levels more than 2000 m above S.L.

Also the agricultural areas of the bigger and smaller farmers (e.g. at bottom), the artificially irrigated fields bearing high-value crops (dark yellow), and the pastures without major additional irrigation appearing in white to light green hues are clearly discernible.

The Yellowstone region is known throughout the world for its volcanic features. Even today mud volcanoes, hot springs and geysers can be observed as relicts of the former volcanic activity.

One of the most conspicuous forms in the picture is the almost circular Island Park Caldera, the crater with the brownish edge half-way between Yellowstone Lake and the left lower corner. It is a huge sunken caldera of a former volcanic cone of abt. 30 km diameter. Inside the crater smaller "parasitic" volcanoes (5 small brownish cones) can be discerned.

#### 2.5. Süßer See (MKF 6 - aircraft, Fig. 7)

This colour synthesis image produced for geographic interpretation was synthesized from MKF 6 photographs taken from an aircraft flying height of 6530 m. The detailed interpretation and description of the picture was published in /4/.



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