SPACEBORNE STEREO-PHOTOGRAPHY FOR MAPPING OF HIGH MOUNTAIN TERRAIN

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Abstract

For the mapping of remote high mountain areas spaceborne stereo-photography represents an essential and effective tool. In this paper the results of comparative empirical investigations into the use of different data for relief mapping are given. Photographs of Earth Terrain Camera, Metric Camera, Large Format Camera and SSEOP Hand Held Hasselblad Camera have been tested. Moreover, remarks on usefulness and information content of these stereo-data for thematic mapping are given. The studies have been carried out in various ranges of the Himalaya.

1 Introduction

Despite the fact that topographic and thematic mapping by means of non-photographic spaceborne stereo-imagery (SPOT, SIR, Landsat TM) is gaining more and more importance, space photography still provides that source of three-dimensional terrain information which offers the highest spatial resolution and therefore most details. At the same moment it also provides the possibility to observe and map comparatively large areas.

Stereo-photographs will be acquired during most manned space missions. This is why mapping using spaceborne stereo-photography will in the future still have its justification, even so because digital auto-stereocorrelation will facilitate stereo-mapping of remote high mountain terrain.

2 Cameras and Imagery

In order to relativate the topographic and thematic mapping results it is advisable to have a look at the types of cameras and films used. Table 1 summarizes various interesting parameters of the imagery investigated.

3 Disposition of Data Acquisition

The geometric relation between image size, focal length, flying hight and areal equivalent in nature may be best explained by representing it in graphical form. Figures 1 — 4 show the image format (top left) and the maximum altitudes in terrain as hatched areas. The areal equivalents are given beside/in the ground sketch of the respective overlap. The LFC configuration only represents a medium value (270 km) perigee (240 km) and apogee (370 km) of the Space Shuttle of 370 km and 240 km respectively.

4 Accuracies in Topographic Mapping

The possibilities of photogrammetric evaluation of space photographs have been tested in various regions of the Himalaya Range (Fig. 5) by restitution of image pairs of the systems described in section 2 and 3. For a discussion of image and model geometries and various problems concerning major elevation differences and earth curvature respectively, the reader is referred to the remarks given by Kostka 1987 [8].

For the estimation of the achievable planimetric and hight accuracies, approximation formulas based on empirical data, which take into consideration the particular conditions of space stereo–photography, are given in Tab. 2 and 3 (Kostka 1987 [8]).

Numerous mapping tests in the Hindu Kush–Himalaya Region for the evaluation of photographic space imagery, the results of a representative number of which (Fig. 5) are given in Tab. 4, demonstrate the possibilities and limitations of the application of space photography for topographic mountain cartography (Mansberger 1987 [10]). Accuracy has been calculated by comparing arbitrary, surveyed contour line points in the resulting test maps and in available medium to large scale reference maps (Fig. 5).

What can be achieved in contour line mapping under favourable conditions (cf. Buchroithner 1987, 1988 a [3,4]) is demonstrated in the LFC evaluation given in Fig. 6. More examples (operator R. Mansberger) displaying contour lines and drain and ridge lines as well as the outlines of glaciers and perennial snow are given in Kostka 1987 [8] and Buchroithner 1988 [5]. They drastically show the restrictions caused by shadow and cast shadow, snow cover, clouds and cloud shadow.

5 Thematic Mapping

Geological (Buchroithner 1984 [1]), geomorphological (Buchroithner 1985 [2]), glaciological (Kostka 1987 [8]), meteorological/climatological (Lazar 1987 [9]), vegetation and land use studies (Huss and Kostka 1987 [6], Huss, Kostka and Dobremez 1987 [7]) have been carried out using 23 x 23 cm^2 Metric Camera colour infrared film positives at an original scale of 1 : 820 000. Scenes of the Hindu Kush-Himalaya Region have been evaluated on a light table by means of conventional mirror stereoscopes using magnifications corresponding to scales up to approx. 1 : 50 000. It is obvious that for supraregional and detailed thematic — and in particular geological — studies different magnifications have to be used in an alternating, interactive manner. Geological/geomorphological studies of Large Format Camera colour infrared stereo-pairs of W Pakistan are still under way. The enormous benefit of the three-dimensional information, also for thematic mapping is beyond any doubt. Fig. 7 represents a geological mapping example based on MC imagery.

For many thematic evaluations high geometric accuracy is not an indispensible prerequisite. Therefore the required interpretations can directly be carried out from unrectified stereo–photographs. In most cases the differences between topographic reference maps and images of the same scale are neglegibly small (i.e. some mm maximum at 1 : 50 000) over distances up to some tens of km (Buchroithner 1984, Gierloff–Emden, Dietz and Halm 1985 [2]).

Vegetation and land use studies in the W Hindu Kush and E Himalaya processing digitized Metric Camera CIR photographs in an image processing system yielded remarkable results (Huss and Kostka 1987 [6], Huss, Kostka and Dobremez 1987 [7]), despite the drawbacks due to illumination effects (shadow).

6 Satellite Trekking Maps – Useful Application of Space Photography

The Institute of Applied Geodesy and Photogrammetry of the Graz University of Technology, which closely cooperates with the Institute for Image Processing and Computer Graphics in Graz, has produced a satellite trekking map (Sattrek Map) of the Solu Khumbu Region in E Nepal. Due to the already mentioned negligible differences in geometry in the central portion of the Metric Camera photographs, it seemed justified to use an unrectified image for a simple three-colour print to produce a mountain trekking map.

An original CIR diapositive of the desired region has been screened to a final scale of 1 : 250 000 and asigned colour brown for printing. By means of mirror stereoscope interpretation the major drainage system and the outlines of glaciers have been traced, their geometry beeing determined by the screened diapositive. This line map was eventually printed in blue. Planimetric details (routes, passes, settlements, air fields and names) were — based on available collateral information — added in black colour.

The three–colour print results in an image map which in some respects, e.g. geometric accuracy, has to be taken as an approximation but to a great extent satisfies the users' wishes for map information relevant for Himalayan trekking. The advantage of this type of map is that its preciseness as well as its information content is considerably higher than that of all previously purchasable trekking maps. Reasonably high production runs provided, such maps could be produced in a fast and simple way and sold for a comparatively low price for touristic regions where no other trekking maps of equivalent quality exist.

7 Concluding Remarks

Based on several extensive tests in various regions of different terrain type in the Himalayan belt, the benefits of spaceborne stereo–photography for the extraction of information about remote mountainous terrain are evident. For many purposes, the accuracies achievable in relief mapping seem satisfactory. For thematic mapping, on the other hand, relief information in many cases is an essential issue. Future auto–correlation of stereo–models of space photography will still increase its potential.

8 Acknowledgements

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Table 1: Camera and film parameters of the stereo–imagery used for mapping tests. Note that the ETC and the SSEOP Hasselblad camera are not metric.

	Earth Terrain Camera	**Metric Camera**	**Large Format Camera**	**Space Shuttle Earth Observ.Proj. (SSEOP) Hand-Held**
Camera:	ETC S-190-B	Modified Zeiss RMK-A-30/23	ITEK NASA LFC	Modified Hasselblad 500-EL/11
Lens	—	Zeiss Topar A1	Metritec 01	—
Focal Length	475 mm	305.128 mm	30.5.882 mm	—
Format	11.5 x 11.5 cm^2	23.0 x 23.0 cm^2	23.0 x 46.0 cm^2	6.0 x 6.0 cm^2
Max. Distortion	10 μm	6 μm	10 μm	—
Resolution	70 lp/mm	39 lp/mm	—	—
Image Angle	14° and 20° in diagonale	41° and 56° in diagonale	41°/75° and 80° in diagonale	—
Motion Compensation	yes	no	yes	no
Film:				
Type	Kodak SO-242 Aerial Color Film (Pos.)	Kodak Aerochrome Infrared Film 2443 (CIR, Pos.)	Kodak High Definition Aerial Film 3414 (Panachrom., Neg.)	Kodak Ectachrome 64 Professional Film 6017 (Color, Pos.)
Resolution (high to low contrast)	200 - 100 l/mm	63 - 32 l/mm	800 - 250 l/mm	—
Image Format	11.5 x 11.5 cm^2	23.0 x 23.0 cm^2	22.9 x 45.7 cm^2	5.5 x 5.5 cm^2

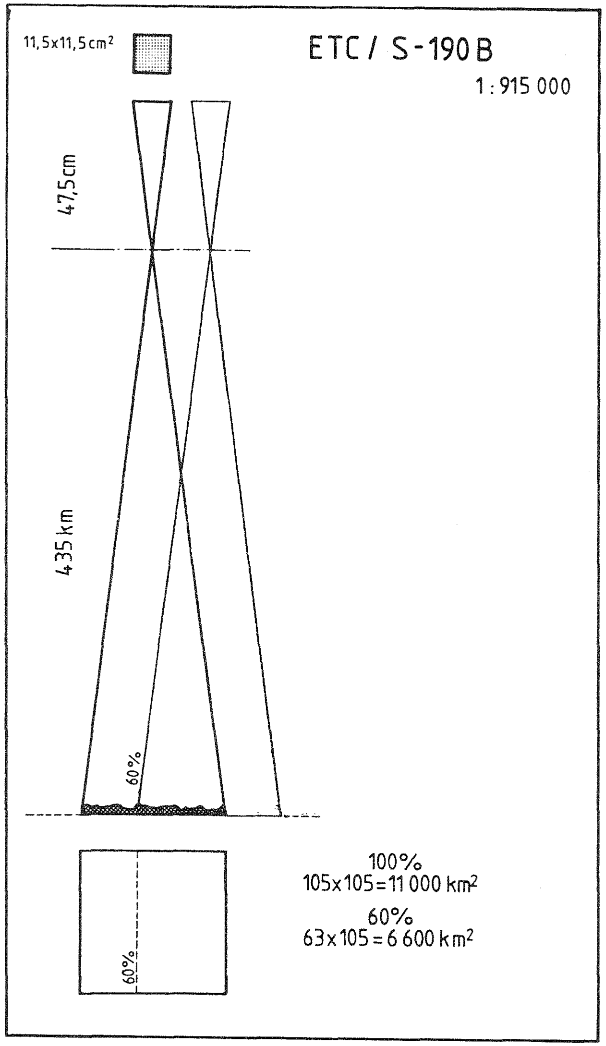

Figure 1: Disposition of camera during the S–190–B Earth Terrain Camera Experiment. Further explanation see text.

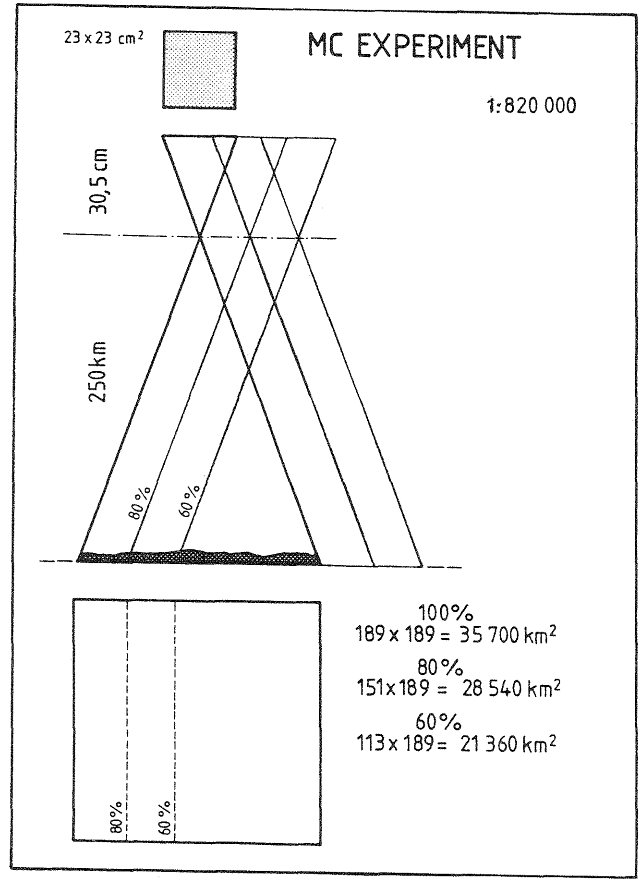

Figure 2: Disposition of camera during the Spacelab Metric Camera Experiment. Further explanation see text.

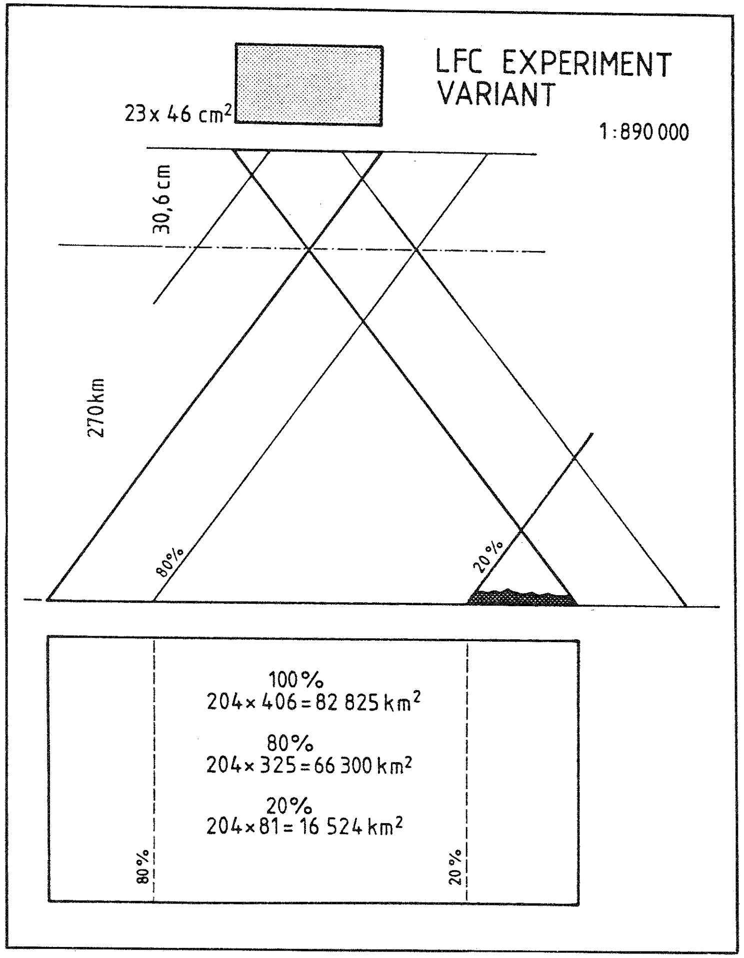

Figure 3: Representative disposition of camera during the Space Shuttle Large Format Camera Experiment. Further explanation see text.

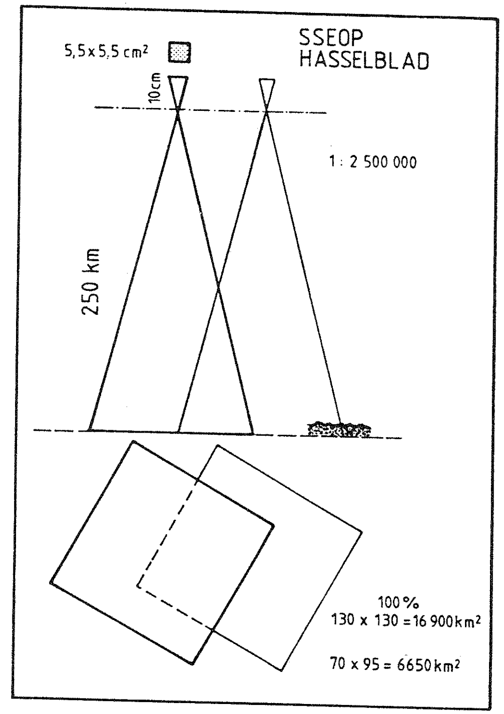

Figure 4: Disposition of camera for the data take of image pair 2708-2709 of orbit 58 of STS 9 Mission (SSEOP).

Table 2: Planimetric accuracies achievable with different spaceborne stereo-photography. Based on empirically derived image coordinate residual errors.

Camera	Film Type	Plotting Device	Position Error in Image x,y (mm)	Image Scale	Position Error in Terrain x,y (mm)
SL - ETC	Colour Film	Jenoptik Topocart B	0,025-0,050	915 000	23-46
STS9 - MC	CIR Film	Zeiss Planimat	0,026-0,038	820 000	21-31
STS41-G/LFC	B & W Film	Zeiss Planimat	0,013-0,020	1 210 000 890 000 780 000	16-24 12-18 10-16
SSEOP Hasselblad / 100 mm	Colour Film	Kern DSR-1	0,010-0,020	2 500 000	25-50

Table 3: Hight accuracies achievable with different spaceborne stereo-photography using different forward overlaps.

Camera	0.08% of Fl. Hight (m)	Parallax Error in Image px	Hight Error in Nature (m) with Varying Overlap		
			80%	60%	20%
SL - ETC	35	0,008 - 0,017	-	75 - 151	38 - 76
STS9 - MC	20	0,009 - 0,013	49 - 70	24 - 35	12 - 17
STS41-G/LFC	30 22 19	0,004 - 0,007	16 - 28 12 - 21 10 - 18	8 - 14 6 - 11 5 - 9	4 - 7 3 - 5 3 - 5
SSEOP Hasselblad / 100 mm	20	0,003 - 0,007	-	34 - 79	-

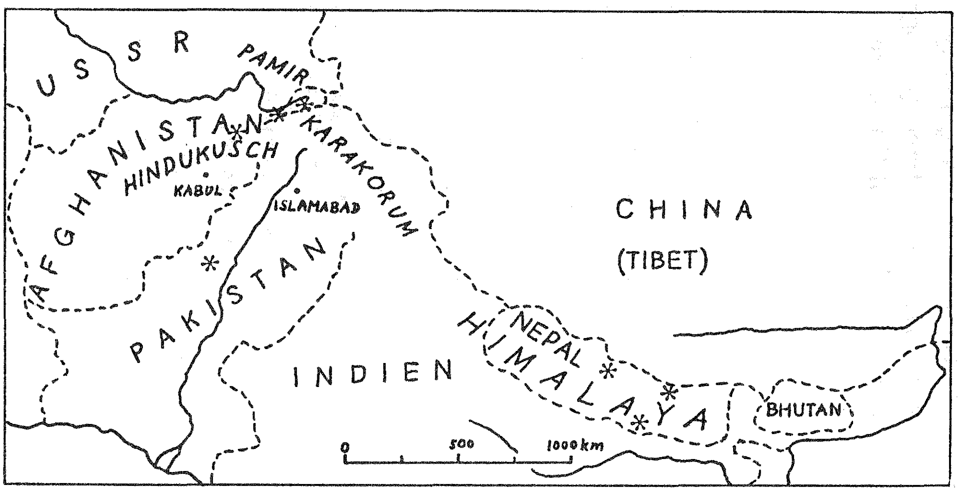

Figure 5: Location diagram showing the test regions for topographic mapping described in Tab. 4. The regions used for thematic mapping are identical or close to those indicated here.

Table 4: Comparison of empirically determined topographic accuracies based on the evaluation of different space stereo–photographs. The ETC and LFC test areas of Langtang Himal and the MC and LFC test areas of Khumbu Himal are identical.

Camera	Earth Terrain Camera (ETC)	Metric Camera (MC)	Large Format Camera (LFC)	Large Format Camera (LFC)	Large Format Camera (LFC)	Hand Held SSEOP Hasselblad
Area	Langtang Himal (Nepal - Tibet)	Khumbu Himal (Nepal)	Langtang Himal (Nepal-Tibet)	Khumbu Himal (Nepal)	Wark-Keshnikhan (Afghanistan)	Wakhan-Eastern Hindu Kush (Afgh.)
Orbit Hight	435 km	250 km	370 km	370 km	270 km	250 km
Focal Length	457,2 mm	305,128 mm	305,882 mm	305,882 mm	305,882 mm	100 mm (Magn .: 398 mm)
Image Format	11,5 cm x 11,5 cm	23 cm x 23 cm	23 cm x 46 cm	23 cm x 46 cm	23 cm x 46 cm	6 cm x 6 cm (23 cm x 23 cm)
Image Scale	1 : 920 000	1 : 820 000	1 : 1170 000	1 : 1170 000	1 : 865 000	1 : 2500 000
Film	Kodak SO-242-Aerial Color (Pos.)	Kodak Aerochrome Infrared Film (CIR)	Kodak 3414-High-Definition Aerial (Neg.)	Kodak 3414-High-Definition Aerial (Neg.)	Kodak 3414-High-Definition Aerial (Neg.)	Kodak Ektachrome 64 Professionalfilm 6017
Plotting Device	Zeiss Planimat D2	Zeiss Planimat D2	Zeiss Planimat D2	Zeiss Planimat D2	Zeiss Planimat D2	Kern DSR-1
Model Scale	1 : 600 000	1 : 400 000	1 : 600 000	1 : 600 000	1 : 600 000	
Restitution Scale	1 : 100 000	1 : 100 000	1 : 100 000	1 : 100 000	1 : 100 000	1 : 100 000
Reference Map	1 : 100 000 HLÄ = 100 M	1 : 50 000 HLÄ = 40 m	1 : 100 000 HLÄ = 100 m	1 : 50 000 HLÄ = 40 m	1 : 25 000 HLÄ = 20 m	1 : 100 000 HLÄ = 100 m
Planim. Accuracy	± 30 m	± 15 m	± 10 m	± 15 m	± 10 m	± 26 m
Hight Accuracy	± 65 m	± 16 m	± 15 m	± 17 m	± 12 m	± 32 m
Contour Line Accuracy	± 110 m	± 50 m	± 35 m	± 40 m	± 30 m	± 150 m

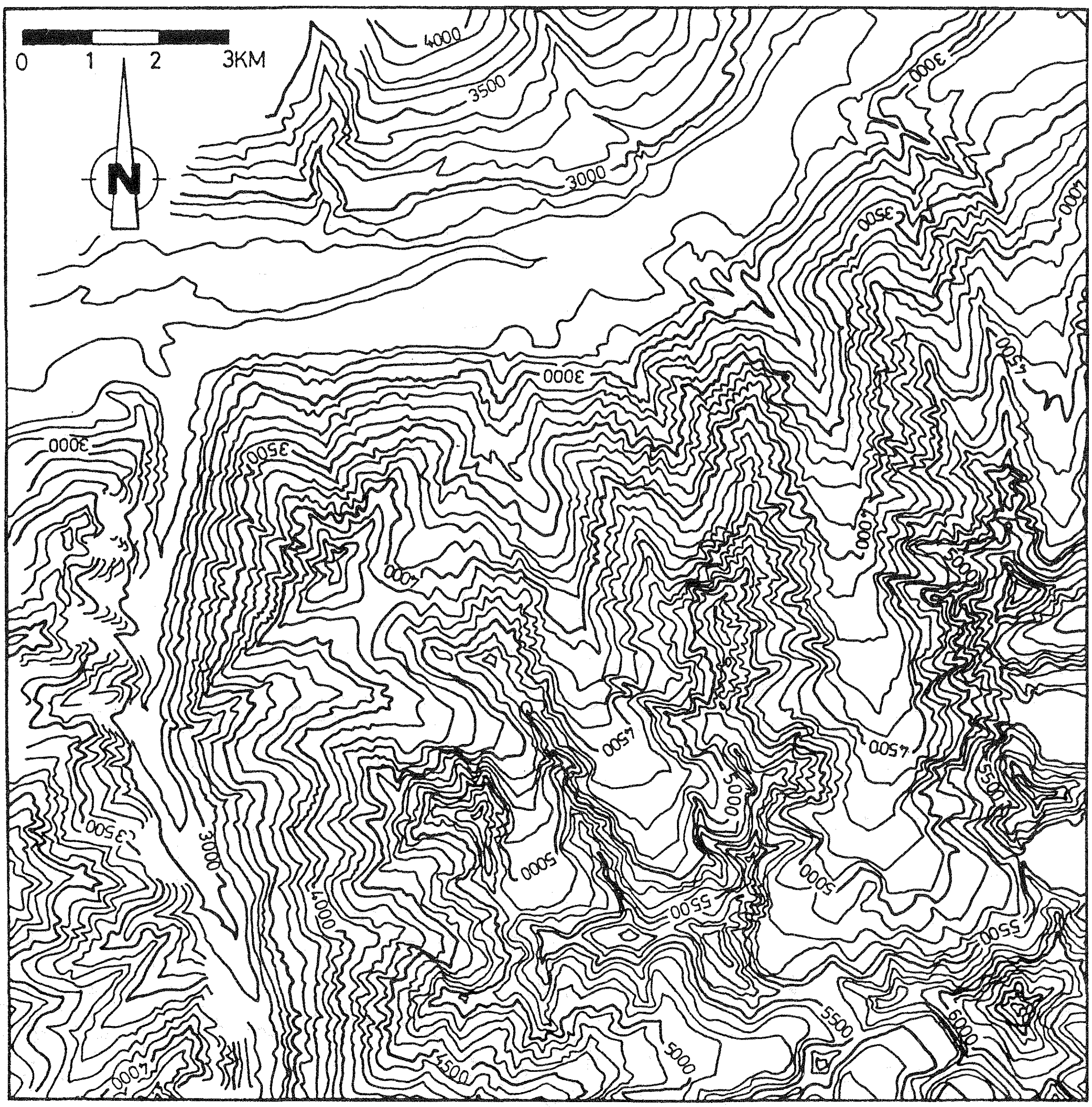

Figure 6: Contour line map of the Wark–Koh–e–Keshnikhan area in NE Afghanistan / Hindu Kush, based on LFC photography. Original restitution scale 1 : 100 000.

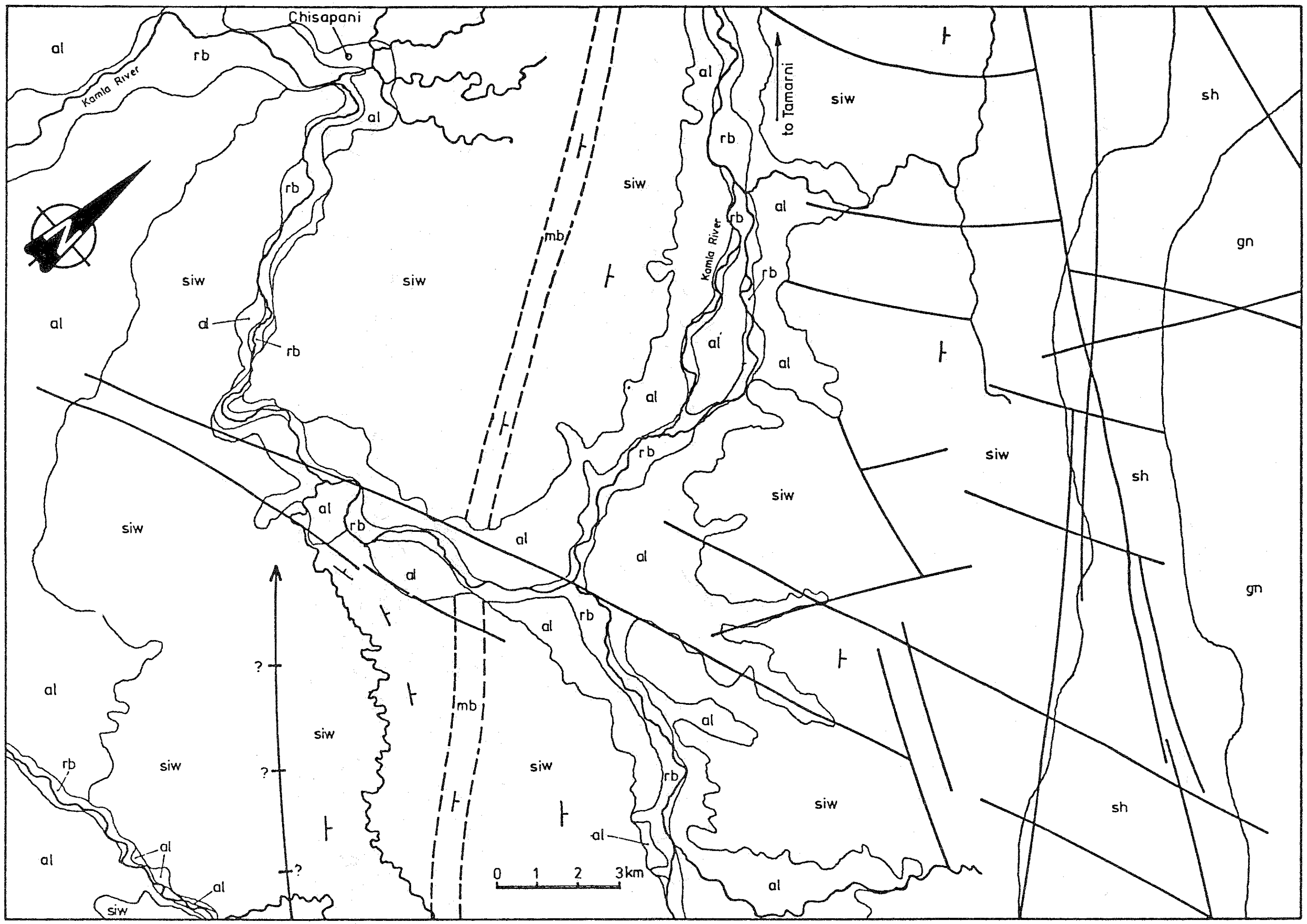

Figure 7: Example of a geological map displaying 6 lithological units derived from Metric Camera colour infrared photographs. The map shows the area where the Kamla River breaks through the Siwalik foothills of the Himalayas into the Ganges Plains (Nepal). Original map scale 1 : 100 000.