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TERRAIN FEATURES MAPPING USING AERIAL PHOTOGRAPHS AND DIGITAL ELEVATION MODEL (DEM) IN THE CAMERON HIGHLANDS, PAHANG

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Abstract: Conventional geological terrain mapping conducted by the Department of Minerals and Geoscience is based mainly on field surveys. Especially for remote areas, it can be very time consuming. Recent developments in remote sensing and Geographical Information Systems (GIS) have led to the development of more advanced methods for the construction of geological terrain maps. Aerial photographs draped over a digital elevation model (DEM) can be used to accurately delineate geological terrain features. This study affirms that the use of aerial photographs and DEM as an efficient, reliable, reproducible and effective technique for geological terrain mapping.

INTRODUCTION

Beginning in 1996, the Department of Minerals and Geoscience Malaysia (formerly known as the Geological Survey of Malaysia) has been conducting geological terrain mapping using the method developed by the Hong Kong Geotechnical Control Office (GCO). The procedure has been adapted to suit current rules and regulations relating to the development and control of highland areas in Malaysia (Zakaria and Chow, 2003).

At the present time, Penang, Kuala Lumpur, Rawang, Gombak, and the Cameron Highlands have already been mapped, while the maps for Bukit Tinggi, Pulau Tioman, Gunung Pulai, Pulau Redang, Lojing, Tanjung Malim, Pulau Pangkor, Kundasang and Simunjan are in progress. (Chow and Zakaria, 2004).

Geological terrain mapping in the Cameron Highlands began in 2002. 1:10,000 scale topographical maps were used as a base, and areas were classified according to the terrain attributes listed in Table 1. Polygons were defined, based on the steepness of the terrain and slope morphology, the activities conducted, and the degree of erosion or instability on that slope(Figure 1).

The polygons in the terrain classification maps were digitized, and combined with Geographical Information System (GIS) software, were used to produce various thematic maps, such as landform, erosion, physical constraints, engineering geology and construction suitability maps. A landform map summarises the broad terrain pattern based on slope angle and terrain attributes. An erosion map can be used by technical and non-technical users who require information regarding the general nature, degree and intensity of erosion, and instability for planning and engineering purposes.

A physical constraints map represents the major physical land resource constraints which affect the terrain. An engineering geology map displays the broad distribution of geological materials, based on their engineering characteristics, and construction suitability map shows the geotechnical limitations of the areas.

Data capture for terrain classification units is traditionally based on field survey. It is time-consuming, especially for inaccessible or remote areas. This study explores a relatively rapid alternative method, using aerial photographs and and a Digital Elevation Model (DEM) to identify geological terrain features.

The study area

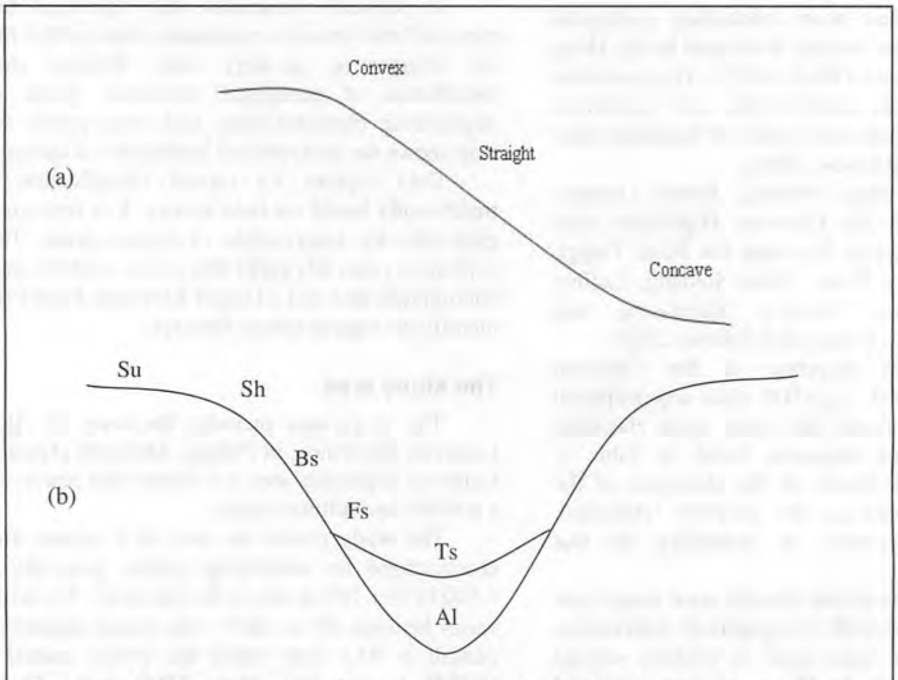
The study area includes the town of Berincang, Cameron Highlands, in Pahang, Malaysia (Figure 2). The Cameron Highlands area is a famous hill resort, as well as a premier agricultural center.

The study covers an area of 6 square km and is characterized by undulating terrain, generally between 1,500 m to 1,760 m above the sea level. The temperature varies between 16° to 26°C. The lowest monthly average rainfall is 93.5 mm, while the lowest annual average rainfall is not less than 2,000 mm. The general topography and settlement of the study area is shown in Figure 3.

SLOPE GRADIENT		TERRAIN CODE			ACTIVITY CODE			EROSION AND INSTABILITY		
$0^{\circ}-5^{\circ}$	1	Hillcrest:		A	Natural	-rock	1	No appreciable erosion:		0
					Slope:	-soil	2			
$6^{\circ}-15^{\circ}$	2	Sideslope:	-straight	B		-soil and rock	3	Sheet erosion:	-minor	1
			-concave	C					-moderate	2
$16^{\circ}-25^{\circ}$	3		-convex	D	Cut Slope:	-rock	4		-severe	3
						-soil	5			
$26^{\circ}-35^{\circ}$	4	Footslope :	-straight	E		-soil and rock	6	Rill erosion:	-minor	4
			-concave	F					-moderate	5
$36^{\circ}-60^{\circ}$	5		-convex	G	Fill:	-rock	7		-severe	6
						-soil	8			
$>60^{\circ}$	6	Drainage valley:		H		-soil and rock	9	Gully erosion:	-minor	7
									-moderate	8
		Flood plain:		I	Terrace:	-rock	a		-severe	9
						-soil	b			
		Coastal plain:		K		-soil and rock	c			
								Well defined recent		
		Littoral zone:		L	Reclaimation:		d	landslip:		
					Mined-out:		e	(diameters)	- < 10m	a
		Alluvial plain:		X					- 10m - 50m	b
					Water bodies:				- > 50m	c
		Wave cut platform:		W		-natural stream	f			
						-man-made chann	g			
		Excavated platform:		Y		-water storage	h	Development of		
						-pond	I	general instability:	-recent	n
									-relict	r
					Colluvial:		m			
								Coastal instability:		w

COVER/VEGETATION			
Soil Slope	Dense Vegetation	No water seepage	a
		Minor water seepage	b
		Moderate water seepage	c
		High water seepage	d
	Moderate vegetation	No water seepage	e
		Minor water seepage	f
		Moderate water seepage	g
		High water seepage	h
	Sparse vegetation (Partially barren)	No water seepage	i
		Minor water seepage	j
		Moderate water seepage	k
		High water seepage	l
	Barren	No water seepage	m
		Minor water seepage	n
		Moderate water seepage	p
		High water seepage	q
Partly soil-Partly covered	Partially covered with concrete/bitumen etc. Dense vegetation in uncovered part	No water seepage	r
		Minor water seepage	s
		Moderate water seepage	t
		High water seepage	u
	Partially covered with concrete/bitumen etc. Moderate vegetation in uncovered part	No water seepage	v
		Minor water seepage	w
		Moderate water seepage	x
		High water seepage	y
	Partially covered with concrete/bitumen etc. Sparse vegetation in uncovered part	No water seepage	A
		Minor water seepage	B
		Moderate water seepage	D
		High water seepage	E
	Partially covered with concrete/bitumen etc. Barren in uncovered part	No water seepage	F
		Minor water seepage	G
		Moderate water seepage	H
		High water seepage	I
	Totally covered with concrete/bitumen etc.	No water seepage	J
		Minor water seepage	L
		Moderate water seepage	M
		High water seepage	N

Table 1: Terrain classification attributes (Zakaria and Chow, 2003)



Su -summit, Sh -shoulder, Bs -backslope, Fs -footslope, Ts -toeslope, Al -alluvium

Figure 1: (a) Slope segment terminology (b) The components of ahillslope (After Richard et al., 1996)

METHODOLOGY

Digitized contour lines on a 1:10,000 topographic map (sheet no Pa.9a 1998) were used to generate the digital elevation model (DEM) of the study area. The linear rubber sheet method was used for interpolation, and a raster DEM produced (Figure 4).

Two black and white aerial photographs with serial numbers F1140 No 125 and F1140 No 126, acquired on 22nd February 1997 by the Department of Survey and National Mapping (JUPEM), were used for this study. The aerial photographs were acquired using Wild Universal Avioson 15 RC4 camera with a focal length of 152.79 mm. Average acquisition altitude was 2780 m. The photographs have a side overlap of 60 percent, and have a scale of approximately 1:20,000. Diapositives of the photographs were scanned at 1000 dpi using Leica photogrammetric scanner, which resulted in an object space of 0.1 m. Diapositives were instead of paper prints because the medium permits measurements of greater accuracy.

Orthorectification and mosaicking

The scanned diapositives were rectified using the features such as roads extracted from topographic map at scale 1:10,000, turning it into orthophotographs. Orthophotographs are plainmetrically true images that represent ground object in their true position and orientation. In order to correct the relief and tilt displacement of the two scanned aerial photographs, a digital elevation model (DEM) and the rotation parameters of the camera were computed. This process is also known as orthorectification (Figure 5).

Twenty-five ground control points (GCPs) were used in the orthorectification. A root mean square error (RMSE) of 0.90 pixels was encountered during orthorectification. The acceptable error for rectification is less than 1.00 (Erdas, 1999). For a better image transformation, a homogeneous distribution of GCPs is suggested, rather than the use of a high number of selected points in the orthorectification process (Trigo and Cerrera, 2000). During image resampling, a cubic convolution resampling method was used to ensure high quality results (Legg, 1994). The orthophotograph was resampled to 0.25 meter per pixel of ground (Figure 5).

The orthophotographs were then used to create a photomosaic of the study area, providing broader coverage than individual photographs.

Interpretation of Aerial photographs

In general, the interpretation of aerial photographs consists of detection and recognition. In this study, features identified and interpreted were digitized directly, using the aerial photographs displayed on the computer screen. The orthophotographs were draped over the DEM, resulting in a 3D visualization. Software packages used for 3D visualization were ERDAS Imagine 8.4 and ER Mapper 6.1. Three dimensional visualization improves the understanding of spatial relationships between image

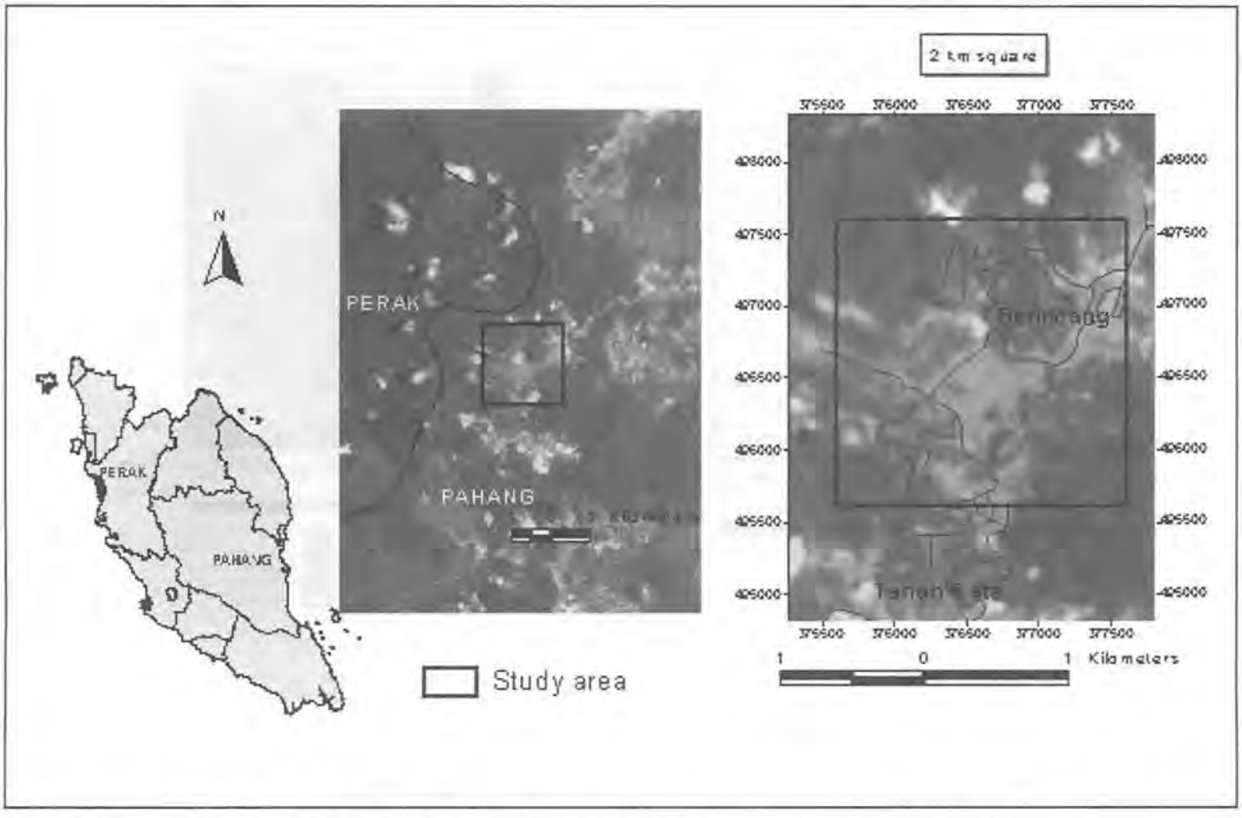


Figure 2: Location map of the study area, located around the town of Brinchang, in the Cameron Highlands, Pahang.

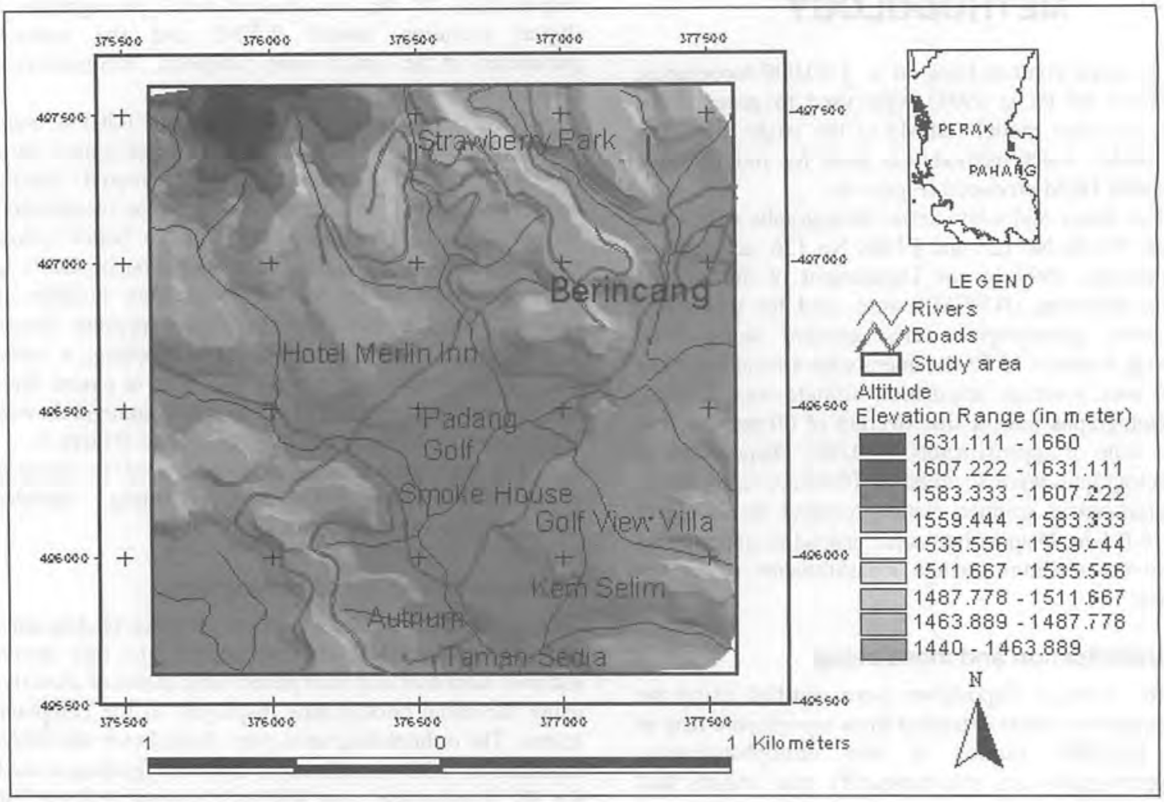


Figure 3: Shaded relief topography and settlement areas

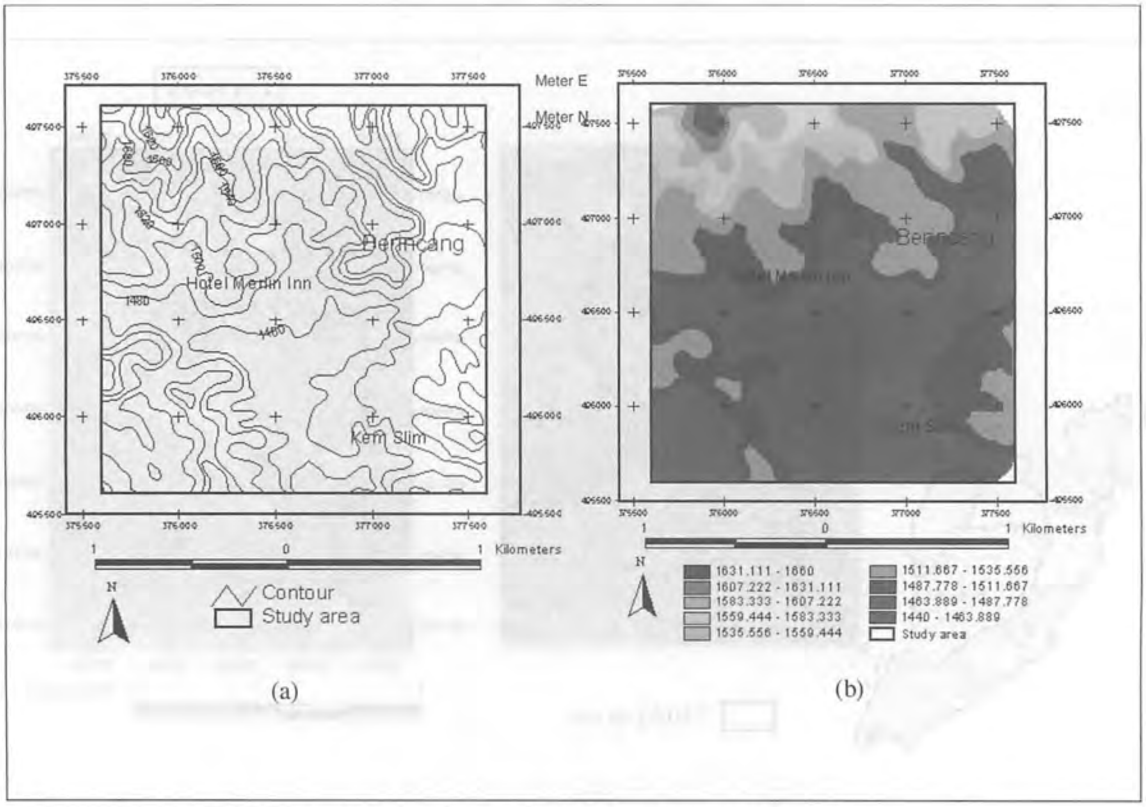


Figure 4: (a) The digitized contour lines; (b) Digital elevation model (DEM)

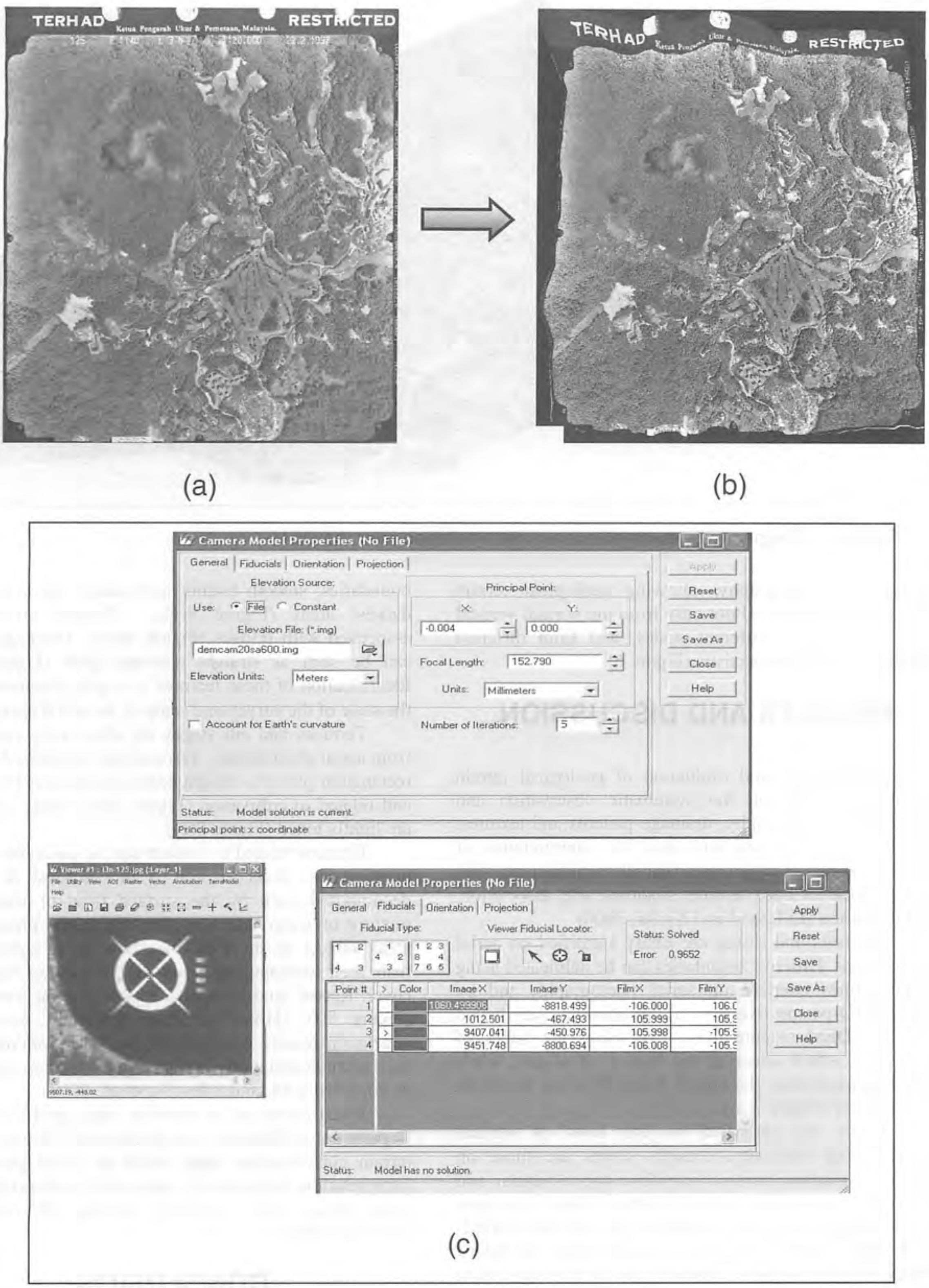


Figure 5: (a) The unrectified 9 x 9 inches aerial photograph; (b) orthophotograph; (c) camera model properties

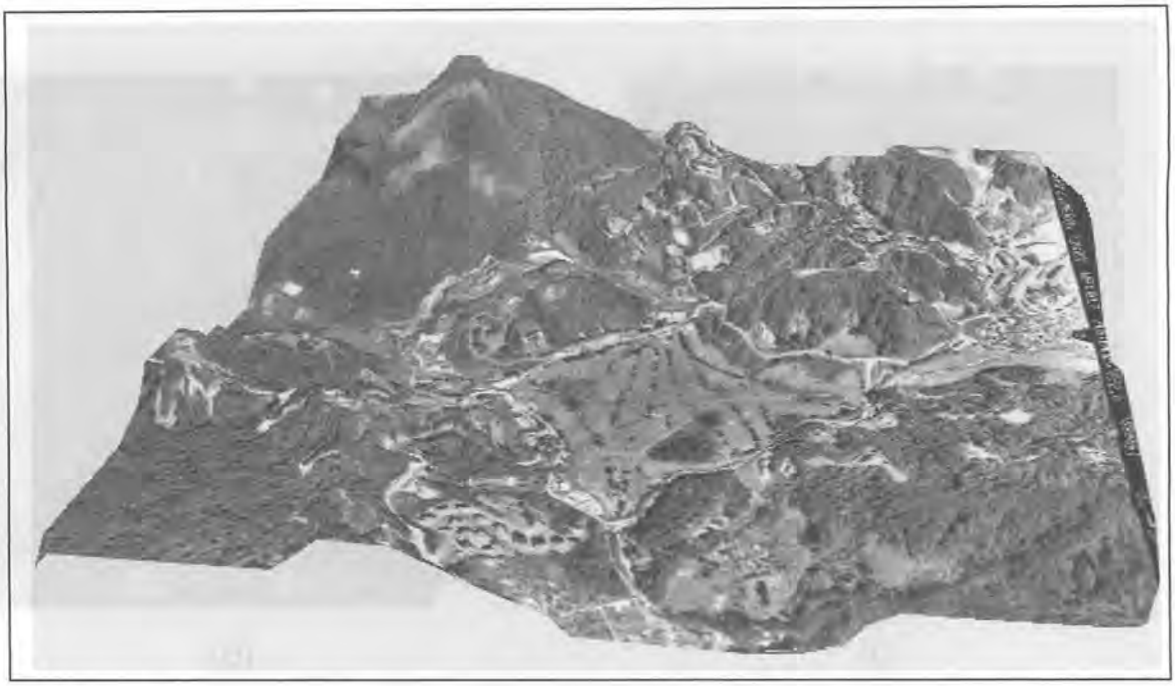


Figure 6: Perspective view of orthophotograph draped over the DEM

texture and topography, allowing geological terrain features to be observed not only from the normal vertical view, but also at different scales, and from different orientations and perspectives (Figure 6).

RESULTS AND DISCUSSION

Identification and evaluation of geological terrain features is based on the systematic observation and evaluation of topography, drainage patterns and textures, erosion, vegetation and land use. The interpretation of aerial photographs uses these basic elements: shape, size, pattern, tone (or hue), texture, shadows, site, association, and resolution (Lillesand and Kiefer, 2000)

Hillcrests and ridges are easily identified on aerial photographs. Hillcrest boundaries can be delineated using contour lines overlaid on aerial photographs, and by viewing 3D-perspective view of orthophotographs draped over the DEM (Figure 7(a)). Footslopes are zones of deposition which occur at the bottom of slopes, while sideslopes comprise the terrain found between footslope and hillcrest (Figure 7(a)).

Slopes are classified on the basis of vertical convexity or concavity. Straight slopes are those on which the gradient does not vary from top to bottom, and is neither convex nor concave (Figure 7(b)). A concave slope will have a higher gradient at the top than towards the bottom (Figure 7(c)), while a convex slope will have a higher gradient towards bottom than at the top (Figure 7(d)). On a concave slope, contour lines will therefore be closer together at the top than towards the bottom (Figure 7(e)), while the opposite is true for convex slopes (Figure 7(f)).

In aerial photographs, water bodies are easily identified. Natural features, such as ponds, have irregular boundaries, smooth texture and usually show up as the darkest areas (Figure 8(a)). Natural streams are associated with bridges (Figure 8(b)). Drainage valleys can be seen as straight drainage lines (Figure 8(c)). Identification of these features is largely dependent upon the scale of the survey and scale of the aerial photograph.

Terraces and cut slopes are also easily recognized from aerial photographs. Terraces are recognized by their rectangular pattern, straight edges and distinct boundaries, and related to cultivation (Figure 8(d)), while cut slopes are lightly toned (Figure 8(e)).

Features related to erosion can be observed in aerial photographs. Sheet erosion is the removal of soil or decomposed rock by the surface flow of water or a mixture of water and sediment. On aerial photographs, areas subject to sheet erosion show up in lighter tones than their surroundings, due to the lack of vegetative cover. Recent landslides also appear as light toned areas (Figure 8(f)). However, relict landslides covered by vegetation require confirmation by field observation. In high altitude aerial photographs, gully erosion may often be confused with landslides (Ng et al., 2002).

When compared to existing maps produced by the Department of Minerals and Geoscience (Figure 9), our terrain classification maps based on aerial photograph interpretation were entirely successful in detecting small water bodies, and accurately locating hill crests and drainage valleys.

CONCLUSION

The 3-D draping technique allows the observation of geological terrain features at different scales, orientations and perspectives. It also allows the use of vertical exaggeration, which was found to be a good for identification, allowing features to be more easily

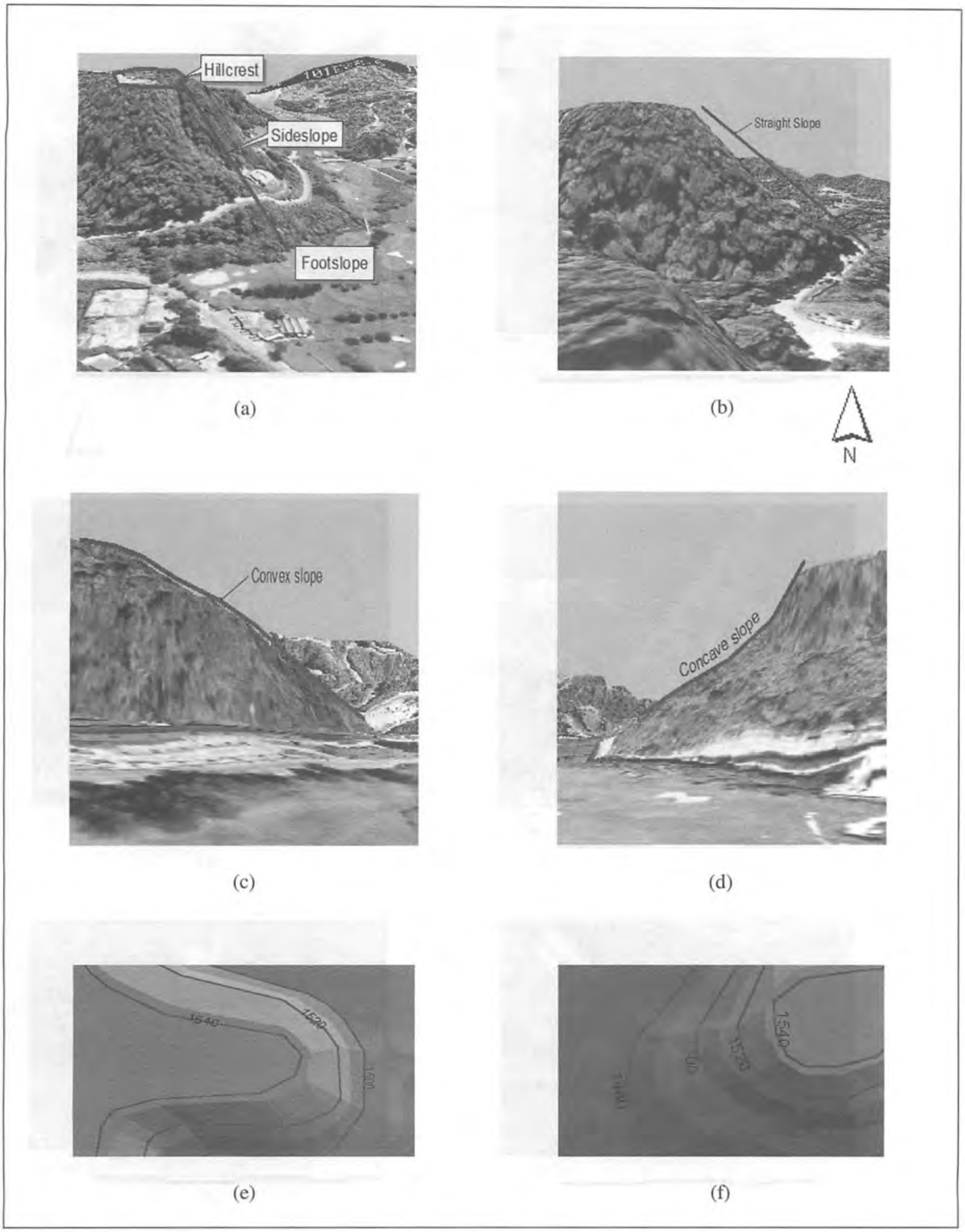


Figure 7: 3-D perspective view: (a) hillcrest, side slope and foot slope; (b) straight slope; (c) convex slope; (d) concave slope; (e) contours for convex slope; (f) contours for concave slope

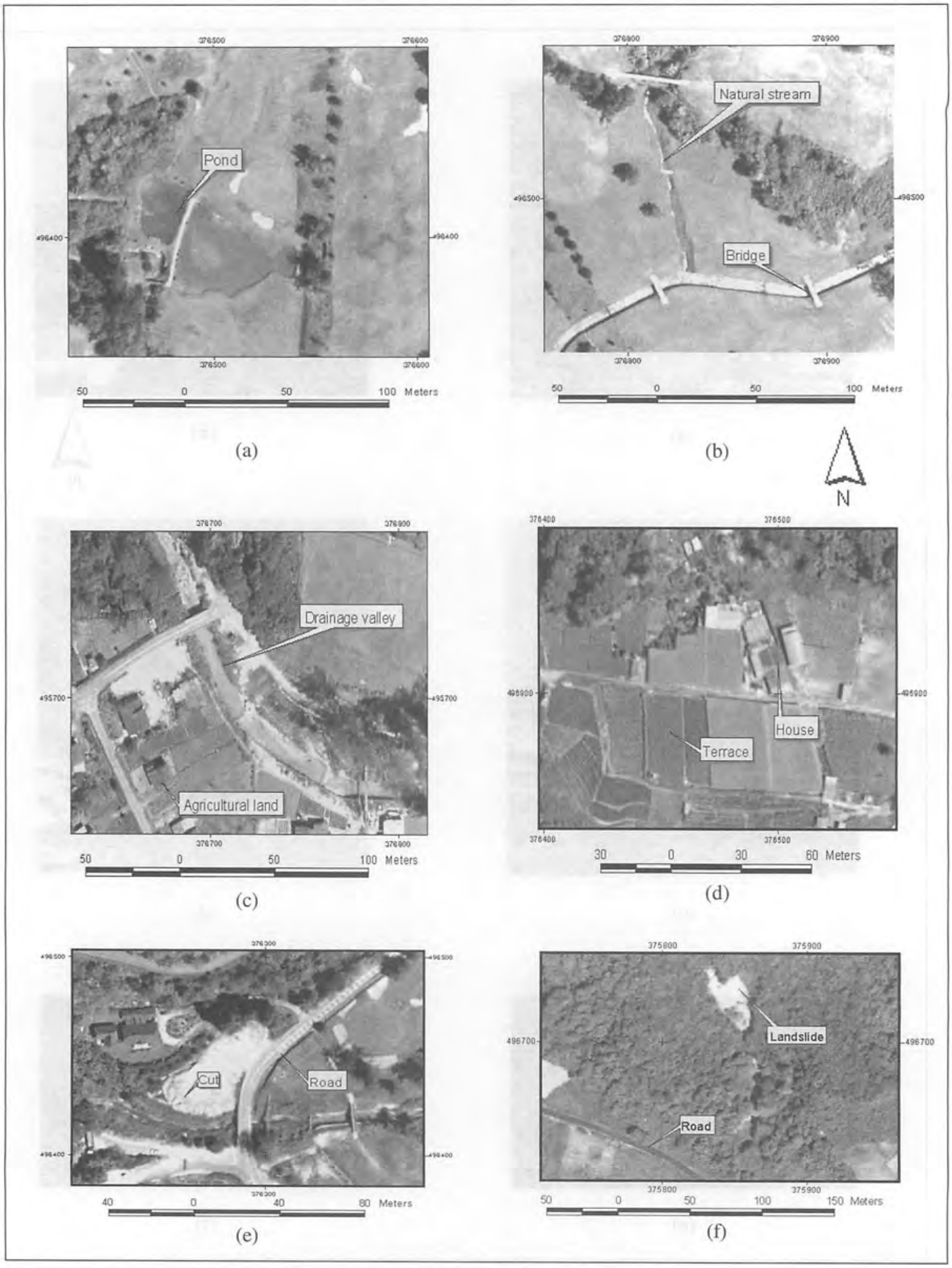


Figure 8: Geological terrain features from orthophotograph: (a) Pond; (b) Natural stream; (c) Drainage valley; (d)Terrace; (e)Cut; (f) Landslide

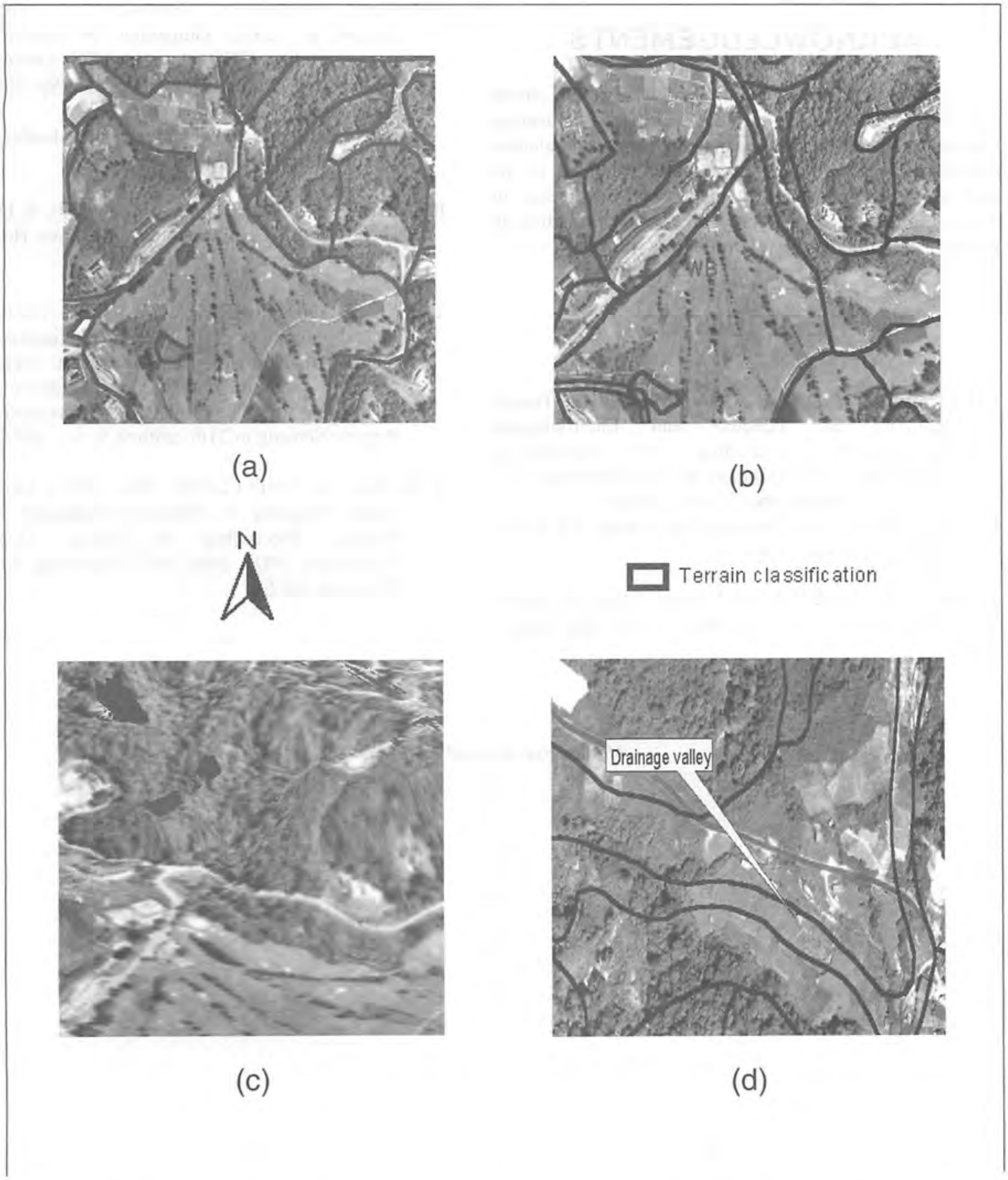


Figure 9: Comparison of terrain classification map (a) based on aerial photographs interpretation; (b) existing map without small size water bodies (WB); (c) incorrect location of hillcrest using 3D draping in existing map; (d) incorrect location of drainage valley in map produced by JMG

identified and spatial relationships to be more easily observed. Orthorectification and mosaicking techniques will save a lot of time in the aerial photographic interpretation of large areas.

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