N13

LANDFORM MAPPING OF FORESTED VOLCANIC TERRAIN FROM SPOT XS DATA

CARTOGRAPHIE DE LA MORPHOLOGIE DES SOLS VOLCANIQUES FORESTIERS A PARTIR DES DONNEES SPOT XS

G. R. COCHRANE (1), M. EDWARDS (1), A. PATERA (2)

(1) Geography Department, University of Auckland, NEW - ZEALAND
(2) Italian National Research Council, Italy

ABSTRACT

Parts of many Pacific islands are characterised by mountainous forested landforms. Rugged terrain, steep slopes and dense vegetation militate against easy access and conventional survey methods using aerial photography and ground surveying for mapping purposes. SPOT multiband (XS) resolution of 20 metres plus synoptic view of a contiguous area of 3,600km2 per scene provides an economic, simple alternative for mapping such areas.

New Zealand is an insular Pacific country but it is not tropical. Never-the-less it shares in common with tropical Pacific islands areas of mountainous terrain, covered by dense stratified forests with steep slopes and difficult access. High effective precipitation often results in deep gorges and in fine textured dissection especially of softer volcanic rocks.

Examples are given of mapping using New Zealand SPOT data where the methods have direct application to tropical environments.

Using visual analysis techniques SPOT photographic data provide excellent first approximation of landforms and geologic units in areas of difficult terrain such as tropical,

mountainous, often heavily forested, deeply dissected, volcanic islands.

RESUME

Une partie des nombreuses îles du Pacifique est caractérisée par des sols montagneux couverts de forêts. Un terrain accidenté, des pentes raides et une végétation dense rendent l'accès difficile et inadapté les méthodes conventionnelles d'étude pour les besoins de cartographie. La résolution de 20 mètres en plus de la vue synoptique d'une zone contigüe de 3 600km2 par prise de vue du SPOT XS apportent une alternative économique et simple à la cartographie de telles régions.

La Nouvelle-Zélande est un pays insulaire du Pacifique mais elle n'est pas tropicale. Néanmoins, elle partage en commun avec les îles tropicales du Pacifique des zones de sols montagneux couverts de forêts denses et stratifiées et comportant des pentes abruptes, le tout étant difficile d'accès. De fortes précipitations entraînent souvent une érosion à texture fine, surtout des roches volcaniques les plus tendres.

Des exemples sont donnés sur la cartographie utilisant les données de SPOT en Nouvelle-Zélande dont les méthodes peuvent s'appliquer directement aux environnements tropicaux.

INTRODUCTION

This paper is part of a broader research project mapping the geology and geomorphology of the Taupo Volcanic Zone (TVZ) from SPOT satellite data (Cochrane, 1989). Mapping of landforms by visual analysis of SPOT photographic products is addressed in this paper.

The TVZ is a complex structural graben of Tertiary and Quaternary volcanics in central North Island New Zealand. It extends some 270km from north to south and varies from 40-120km in west/east width. Broadly known as the Central Volcanic Plateau this area between Tauranga and Lake Taupo is formed essentially of Pliocene rhyolitic rocks with abundant cinerite and pyroclastic deposits from Pleistocene to Recent age.

The New Zealand Geological Survey maps 1:250,000, fig. 1 , Rotorua and Taupo, show the area. Plateaux of ignimbrite often veneered with pyroclastic pumice or tuff, individual rhyolite domes, calderas, volcanic centres, lakes in former volcanic craters, dormant and active composite volcanoes, flanking andesitic mountain ranges, and active geothermal areas all

contribute to the complex patterns present. Active geothermal areas of fumaroles, solfataras, geysers and steam vents although concentrated in the Rotorua Lakes area and the Wairakei area near Lake Taupo are spread throughout the central plateau (Cochrane and Wan, 1983 ; Mongillo, 1989).

Fig. 1 shows a generalised map of the northern third of the TVZ. The eastern margin of the TVZ is flanked by old basement rocks of Mesozoic indurated sandstones (greywackes). These form the uplifted block-faulted highlands of the eastern Ikawhenua and Raungaere Ranges.

The northwestern boundary is also clearly defined. In this area the structural graben of the very flat Hauraki Plains lowland, formed of late Pleistocene fluviatile current bedded gravels and sands, terminates abruptly on its eastern edge against the uplifted western margin of the volcanic Kaimai Range and Mt. Te Aroha volcanic complex. These ranges of Miocene andesites rise in a dramatic fault line (colour figs. N13G, N13H, N13J and N13K).

Small sedimentary basins occur to the east and north of the volcanics (fig. 1, colour figs. N13B, N13D and N13F).

The Tauranga, Maketu and Opotiki sedimentary basins occur to the north between the volcanics and the ocean (fig. 1, 2 and colour figs. N13G.

METHODS

SPOT XS scenes (443/426, 444/426 and 444/427) of the northern part of the TVZ of North Island, New Zealand recorded on 5 August 1986 were selected for evaluation of the SPOT data for landform mapping. The data were contrast enhanced and colour combined (XS 123 : B.G.R.) to produce simulated colour infrared (CIR) photographic images at 1:100,000 scale. Much of the area is forest covered. Visual analysis has included the following processes :

(i) mapping linears
(ii) mapping dissection textures to produce a) simple structural units and b) erosional/lithological units or landform classes.

Landform classes were mapped from the SPOT scenes based primarily on dissection texture patterns.

Measurement of relative relief and prevalent slopes were made from NZMS 260 Series 1:50,000 topographic maps of representative subscenes within each of the mapped landform classes.

Comparisons were made of dissection texture patterns and stream ordering ranking mappable from the SPOT scenes and the NZMS 260 Series topographic maps.

Landform units mapped from the SPOT scenes were compared with NZ geological maps at 1:1 million and 1:250,000 scales. Some examples demonstrating the useful role of SPOT photographic images for the mapping of landforms in difficult terrain are given.

RESULTS AND DISCUSSION

The area selected embraces a diverse range of complex terrain. Mountains, plateaux, hills, interior and coastal plains, interior basins, extinct volcanic cones, estuaries, and numerous lakes are all present. Much of it is forested. Some of it is quite mountainous. Elevations range from 0-1111 metres above sea level. These rise much higher in the eastern ranges beyond the area shown. Although there is a winter maximum of precipitation it is relatively evenly distributed throughout the year. It ranges from 2500-2800mm per annum over much of the area (N.Z. Met. Service 1981). Totals are higher due to orographic effects in the mountains above 600m elevation.

Because of length limitations in this paper only a few examples from a small but representative range of landform classes selected from dissected mountain ranges, plateaux and volcanic dome areas are presented. They demonstrate the useful role of SPOT photographic data for the mapping of landforms in difficult terrain. Many other examples are present.

Comparison of fig. 1, of generalised landform units, with colour figs. N13A and N13G of two SPOT scenes covering much of the area clearly shows that these broad landform units of Fig 1 can be readily subdivided using SPOT images. Similarly additional details of landforms can be mapped from colour fig. N13F showing part of SPOT scene 444/426.

SPOT image 444/427 (colour fig. N13A) shows some of this complex pattern. Detailed enlarged selections of some of these major landform classes analysed on the basis of dissection texture and patterns are shown in colour figs N13B, N13C, and N13D. Boundaries and subdivisions of landforms in SPOT image 443/426 (colour fig N13G) are shown as a simple generalised map in fig. 2. Satellite and ground photos of the Kaimai Range are shown in colour figs. N13H, N13J and N13K. An enlarged subscene of the extremely dissected western Mamaku Plateau is shown as colour fig. N13I. This differs considerably from other areas of the plateau (fig. 2, Mamuka plateau areas a, b and c).

OKATAINA VOLCANIC CENTRE

The complex Okataina Volcanic Centre (OVC) including the Rotorua Lakes area occupies a central location (fig. 1 and colour fig. N13A). It is flanked on the west, north and east by the Mamaku, Kaharoa, and Kaingaroa Plateaux respectively. Abrupt changes in surface erosion and landform patterns occur south of the lakes. Variations in landforms are present in the Kaingaroa Plateau to the east.

In the enlarged subscene (colour fig. N13C) numerous prominent rhyolitic domes of early mid-Pleistocene age with minimal surface dissection can be seen in the northern half of this region. In the southwest of colour fig. N13C the 14km long dark gash of the Mt Tarawera eruption vent of 1886 at 1111m elevation is shown traversing Mt Tarawera rhyolitic domes. The still bare unvegetated gravel slopes shown as cyan tones. See also colour fig. N13E.

In the northeast the finely dissected dendritic drainage pattern of soft pumiceous Kaharoa Plateau lithologies portrays an area of steep high hills. No former plateau surface interfluves remain.

Snaking between these areas of dissected hills and the relatively uneroded rhyolite domes the smooth texture of the intermontane lowland depicts the flat Recent alluvial valleys of the Tarawera River and its tributaries. See also colour fig. N13B.

Colour fig. N13E shows a ground photo from the Mt Tarawera explosion vent looking northeastwards over the lower dissected hills, past the Recent Volcanic cone of Mt Edgecumbe (colour figs. N13A, N13B and N13F), across the Quaternary sedimentary coastal Whakatane lowlands to the Bay of Plenty (colour fig. N13F). In the extreme northwestern corner is the active White Island volcano, a coastal outlier of the TVZ.

This central OVC area is flanked on the east and the west by the structurally simpler Kaingaroa Plateau (colour figs N13A, N13B and N13C) and the Mamaku Plateau (colour figs. N13G, N13J and fig. 2). These are formed of younger mid-Pleistocene predominantly ignimbrite rocks. The Kaharoa plateau flanking the OVC to the north is formed of still younger late mid-Pleistocene poorly compacted pumiceous breccias. Surface dissection is complex. Much of the area is of an intensively dissected hilly nature rather than a plateau surface (colour fig. N13F).

KAINGAROA PLATEAU

Surface erosional patterns of the Kaingaroa Plateau shown on the SPOT photographic product contrast dramatically between

the northern (colour fig. N13B), middle (colour fig. N13D), and southern sections (colour fig. N13A).

The northern third of the Kaingaroa Plateau (fig. 1) seen as a SPOT subscene image in colour fig. N13B is characterised by a high density dendritic drainage pattern and very fine textured dissection pattern. The surface is one of dissected low hills with numerous ridges, shallow valleys and low relative relief. No original plateau surfaces exist as interfluves. Narrow ridge crests prevail. The eastern margins are flanked by the downfaulted alluvial Te Mahoe and Waiohau basins and the upfaulted western edge of the central axial greywacke ranges (fig. 1 and colour fig. N13B). The plateau is terminated to the north by the very recent symmetric cone of Mt Edgecumbe and the alluvials of the Whakatane lowland. To the west the coarse ranges and the domes of the Okataina Volcanic Centre together form western boundaries.

The central area of the Kaingaroa Plateau west of the downfaulted Galatea Basin (fig. 1) provides a considerable contrast (colour fig. N13D) to the northern part (colour fig. N13B). Drainage is strongly oriented as a series of large parallel widely separated easterly flowing streams in deeply incised narrow gorges. There is very limited lateral tributary development.

Thus broad plateau surface interfluves, transversely cut by widely spaced deep narrow parallel gorges characterise the surface (colour fig. N13D). Landform features differ greatly from the area immediately to the north (colour fig. N13B). Similarly this central area with its characteristic assemblage of landform characteristics differs considerably from the southern third of the Kaingaroa Plateau. The southern third is characteristically a very flat, wide plateau surface with minimal stream dissection other than at the eastern and western fault margins (colour fig. N13A). The SPOT image clearly facilitates mapping the Kaingaroa Plateau landform unit (fig. 1) into three distinct and separate units (colour figs N13A, N13B and N13D).

AXIAL GREYWACKE MOUNTAIN RANGES

The Kaingaroa Plateau is in its turn flanked on the east by the block-faulted,fractured and deeply dissected horst of part of the North Island's central axial mountain ranges of basement Mesozoic greywackes. Strong evidence of structurally fault controlled coarse trellised primary drainage patterns with a secondary dendritic pattern (colour fig. N13F) is evident (colour figs. N13A, N13B and N13D). This landform unit is readily recognised also by its coarse textured dissection, strong concordance of summit levels, a characteristic large relative relief and the dramatic faulted western edge (colour figs. N13A, N13B, N13D and N13F).

MAMAKU PLATEAU

Strong contrasts in landform areas are present in the area covered by SPOT scene 443/426 (colour fig. N13G). The Mamaku Plateau occupies much of the eastern half of this area (figs. 1 and 2). Colour figs. N13G and N13H show that the Mamaku Plateau area has a varied range of landforms and is much more complex than the simple pattern derived from the NZ Geological Map (Healy et al., 1964) as shown in fig. 1. Formed of weakly welded ignimbrite this plateau dips gently to the north from a maximum elevation of near 600m in the south. In the west erosion is severe from the numerous westward draining tributaries of the Waihou River. Frequent narrow parallel valleys closely dissect the southern part. The valleys rise laterally very steeply to narrow crests and alternating narrow interfluve areas (colour fig. N13I). An intermediate form with narrow moderately deep U-shaped gorges with broader interfluves characterises the central lower Kaimai (area b in fig. 2). One of New Zealand's major kiwifruit orchard areas is located in the north at Te Puke (c in fig. 2) on gently sloping broad interfluves. Steep hills in the north with dendritic drainage, an adjacent quite mountainous area and a large domed area (rhyolite) in the south with only minimal surface erosion (colour fig. N13D, N13G and N13I) are clearly different landform units within the broad generalised Mamaku Plateau division of fig. 1.

HAURAKI PLAINS AND KAIMAI RANGES

To the west of the Mamaku Plateau, the Hauraki Plains graben, and the horst of the western edge of the Kaimai Range and Mt Te Aroha mid-Tertiary andesitic volcanics form sharp landform boundaries. They also add to the complexity and distinctiveness of the landform units. The Hauraki Plains, formed of very late Pleistocene current bedded sedimentaries, is one of the flattest areas in New Zealand (colour figs. N13G, N13H, and N13K). The coarsely dissected andesitic rocks of the northern half of the Kaimai Ranges rise abruptly as forested mountains to over 1000 metres at Mt Te Aroha (colour figs. N13G and N13H).

Broad open valleys (colour fig. N13H), few tributaries and a high relative relief characterise the landforms of the mid-Tertiary andesites of the Kaimai and Te Aroha volcanic complex forming the dramatic fault edge of the northern part of the Kaimai Ranges (colour figs. N13G, N13H, N13K, and fig. 2). These differ from the short steep valleys with narrow transverse profiles of the strongly welded Pliocene ignimbrites forming the eastern flanks and southern edges of the Kaimai Ranges (figs. N13J and N13K). Surface dissection is much less than on the weakly welded mid-Pleistocene ignimbrites of the Mamaku Plateau immediately to the east.

CONCLUSION

SPOT XS photographic products at scale of 1:100 000 were used for landform mapping primarily using dissection texture to map landform classes. Much of the area is mountainous and densely forested. This analysis demonstrated that the technique is practical and economic. It provides a useful first approximation for landform mapping where data may be sparse or lacking. It is useful for updating existing maps. It is especially valuable for mapping areas of rugged terrain and difficult access. SPOT products are superior to LANDSAT RBV for landform mapping (Cochrane & Browne, 1981).

The results from this analysis share common problems of mapping forested volcanics of many Pacific islands. The technique requires minimal equipment and uses conventional photo interpretation and photo geological techniques to map areas of difficult terrain. The spatial resolution of the SPOT XS data plus the synoptic view provides a better tool for and a more rapid method of broad geological mapping of structures, dissection textures and landform classes than does aerial photography. Preliminary comparison of mapped landforms with geological and topographic maps show good agreement with more detail usually present on the SPOT photographic products. Further field mapping suggests that updating, improvement,and modification of some existing maps is likely.

The use of SPOT PAN products has not been tested. Potentially such data should provide even better results for mapping landforms. Future plans include digital analysis merging SPOT PAN, LANDSAT TM and digital terrain data (DTM) for detailed landform mapping. Although more rapid and very acurate and detailed such analyses are dependent upon access to sophisticated image processing facilities and interactive software such as "IGIS" (Cochrane, 1989).

ACKNOWLEDGEMENTS

The authors wish to thank Jonette Surridge, University of Auckland Department of Geography for draughting, and Brian Hurst, Department Photographer for photographic assistance. Dr. A. Patera acknowledges financial support from the Italian National research Council. The University of Auckland Research Committee provided Professor G. Ross Cochrane with research support which is gratefully acknowledged.

REFERENCES

COCHRANE G. Ross, 1989. IGIS - Image processing for geological mapping. Unpublished paper presented at *15th NZ Geography Conference Dunedin.*

COCHRANE G. Ross, G.H. BROWN, 1981. Geomorphic mapping from LANDSAT III Return Beam Vidicon (RBV) Imagery. *Photogrammetric Engineering and Remote Sensing* 47 : 1205-1213.

COCHRANE G. Ross, T.F. WAN, 1983. Interpretation of structural characteristics of the Taupo Volcanic Zone, N.Z. from LANDSAT data. *International Journ. of Remote Sensing* 4(1) : 111-128

HEALY, J., J.C. SCHOFIELD, B.N. THOMPSON, 1964. Sheet 5, Rotorua, Geologica Map of N.Z., 1:250 000, DSIR, Wellington Mongillo M.A. 1989. Video Thermal Infrared Surveys Of New Zealand Geothermal Areas. *Proceedings 15th NZ Geography Conference:* 230-234.

N.Z. MET. SERVICE. 1981. Summaries of Climatological Observations to 1980. NZ *Met. Service Miscell Pub.* 177.

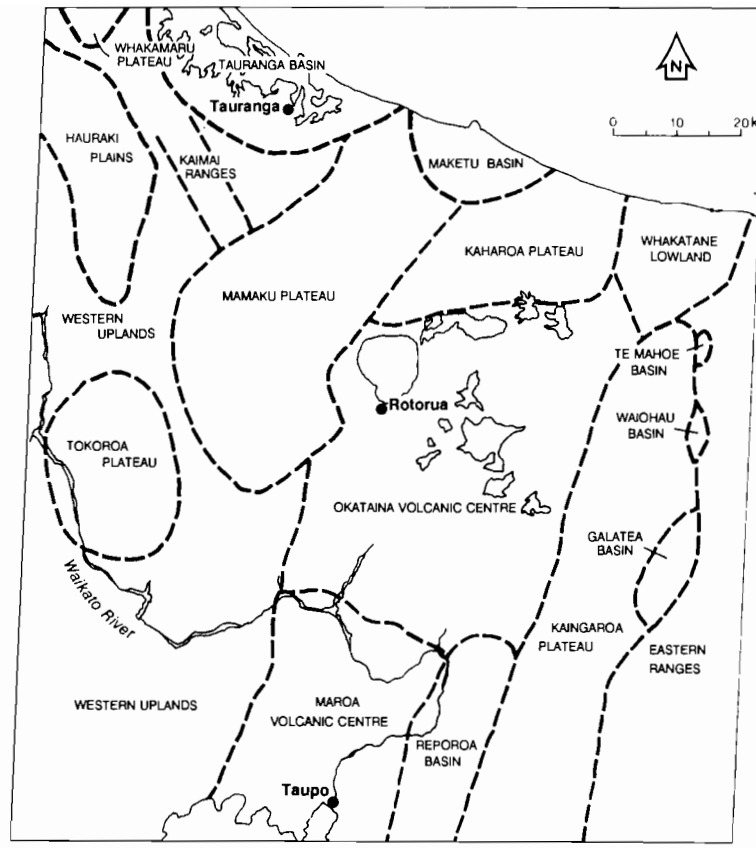


Figure 1 : Generalised landform categories of Central Volcanic Zone (CVZ), North Island, N.Z. Geological Survey map (Healy et al., 1964).

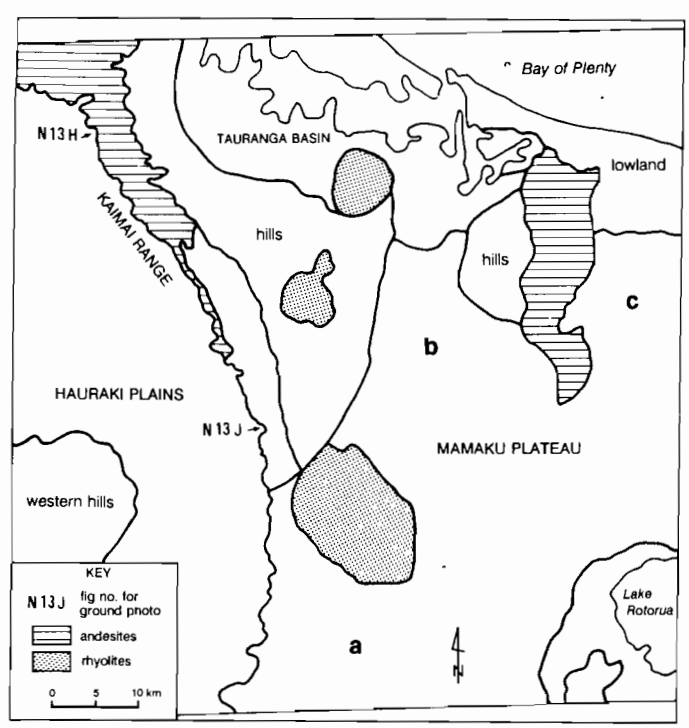
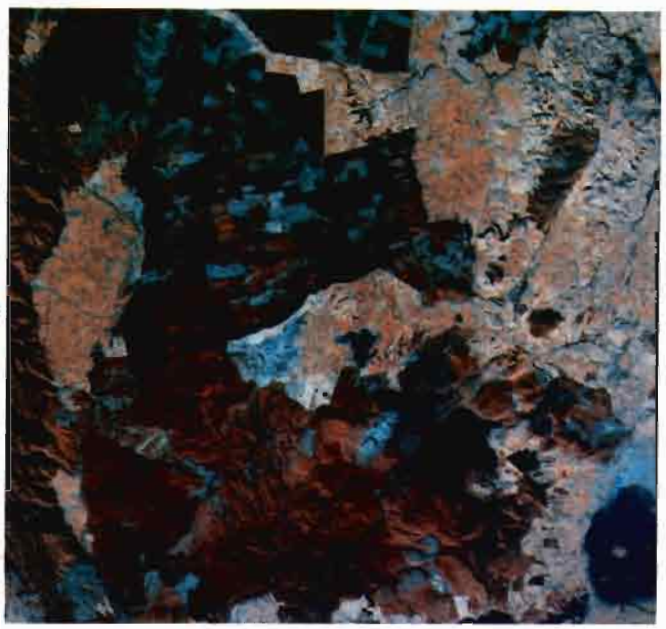
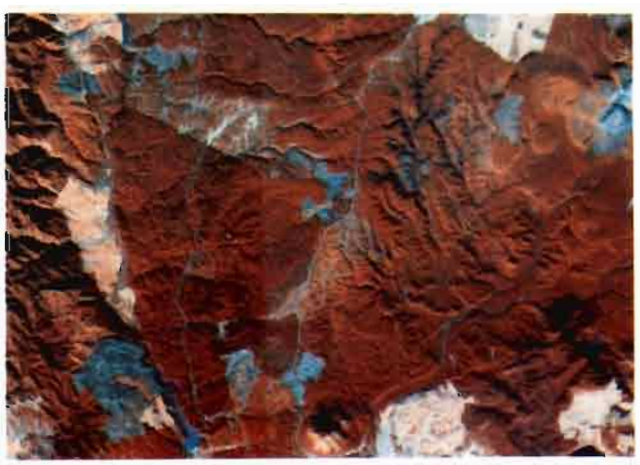


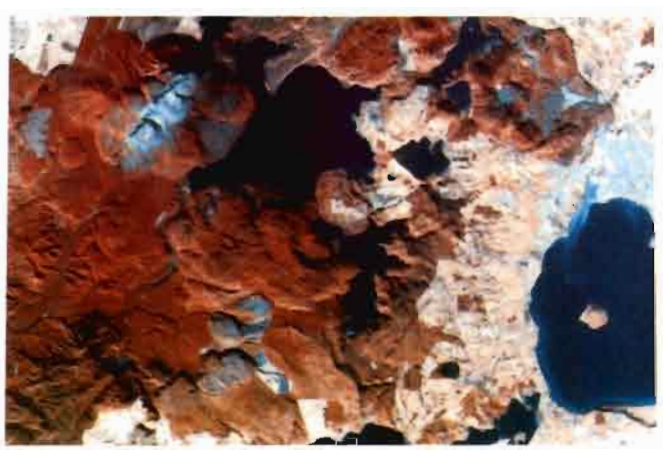
Figure 2 : Generalised map of landform units of colour fig. N13G based on analysis of dissection textures.



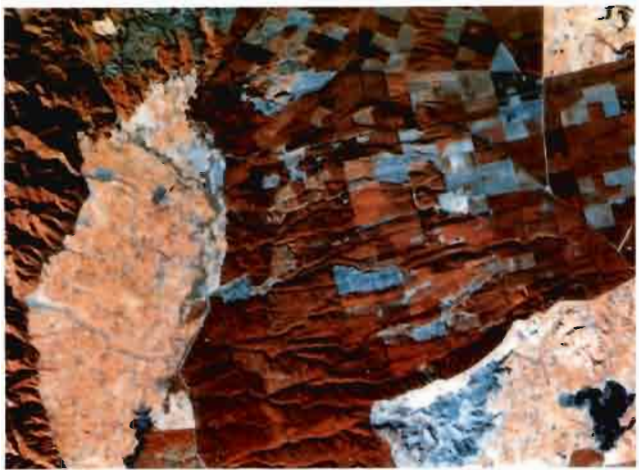
N13A : SPOT XS scene 444/427 of part of CVZ. Okataina volcanic mountain and Lake complex (west, left) ; Kaingaroa Plateau (centre) and Ikawhenua Ranges (eastern margin).
c CNES 86/Dist.SPOT IMAGE

N13B : SPOT subscene showing finely dissected but not deeply incised northern part of Kaingaroa Plateau flanked by coarse ranges to west alluvial lowlands to north, and basins and greywacke ranges to the east.
c CNES 86/Dist. SPOT IMAGE



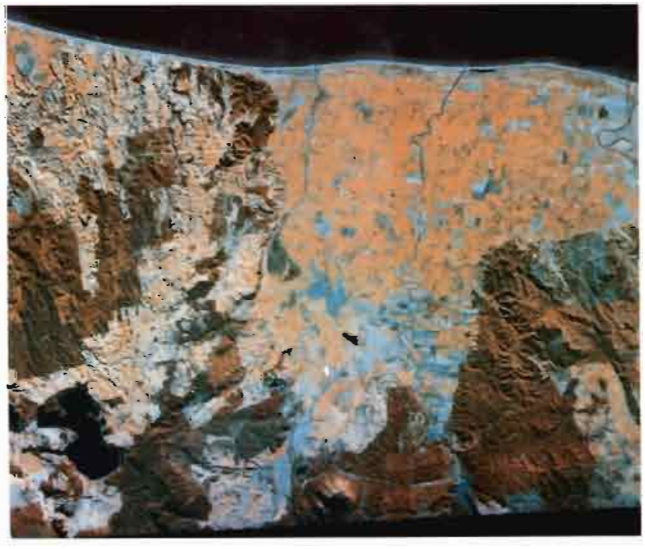


N13C : SPOT subscene of Rotorua lakes - rhyolite dome mountain complex. Note the limited erosion on the domes, the bare gravel slopes and the long dark gash of Mt. Tarawera crater in the southwest and the Tarawera River alluvial valleys in the north east.
c CNES 86/Dist.SPOT IMAGE



N13D : SPOT subscene of the central Kaingaroa Plateau (western two thirds), Galatea Basin and Ikawhenua Ranges. Note the coarse parallel drainage on the plateau.

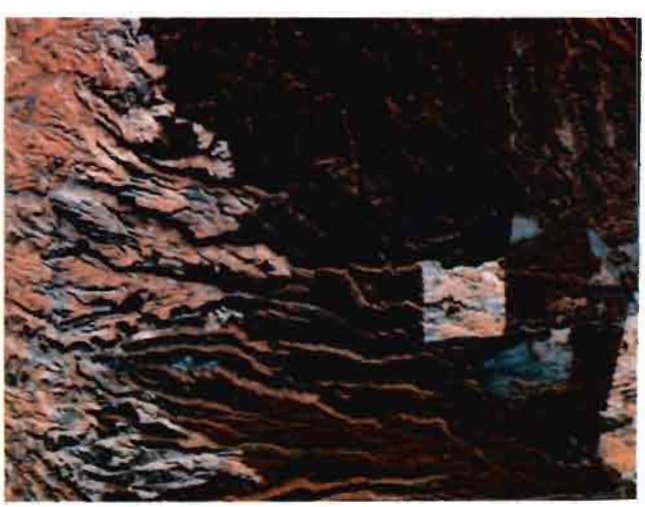
N13E : Ground view looking north east along Mt. Tarawera explosion chasm, across the lower dissected hills to the volcanic cone of Mt. Edgecumbe. The Whakatane lowlands and Bay of Plenty lie beyond.



N13F : SPOT subscene (west-left to east). Finely dissected volcanic hills Whakatane Lowland with Tarawera, Rangitaiki and Whakatane rivers and faulted coarsely dissected greywacke Raungaeke Range.Mt. Edgecumbe volcanic cone is conspicuous near the central southern edge.

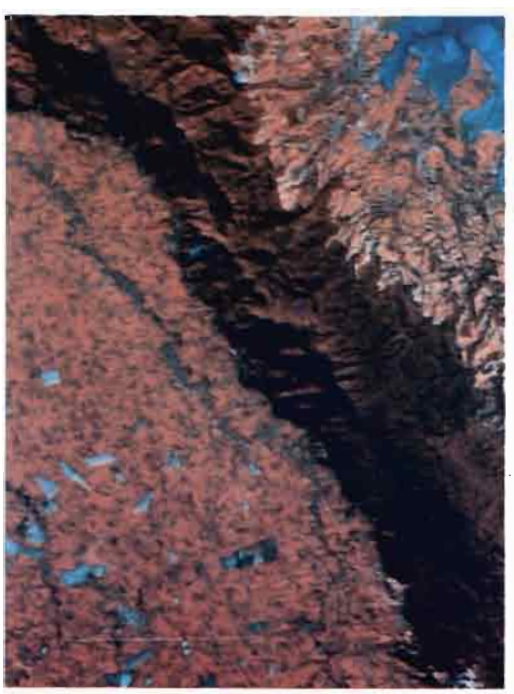
N13G : SPOT scene
443/426 of part of CVZ.
Compare with fig. 2

N13H : Ground view from Hauraki Plains looking east to the coarse broad valleys of the faulted western edge of Miocene andesites of the northern part of the Kaimai Range. See colour figs. N13G, N13K and fig. 2.



N13I : Westward flowing tributaries of the Waihou River have carved deep steep-sided parallel gorges into the forest covered western par of the Kaingaroa Plateau. The northern central area is a forest clad massive rhyotitic dome with very shallow widely spaced coarse drainage patterns. Predominantly parallel drainage in deep gorges reappears in the forested Kaingaroa Plateau ignimbrites in the north east. Pastures (pink tones) cover the lowlands on the west.

N13J : Faulted western margin of forested southern Kaimai Ranges formed of highly welded Pliocene ignibrites. See colour fig. N13K.



N13K :SPOT subscene of Hauraki Plains Kaimai Ranges and Tauranga low lands. Note contrasts between northern and southern parts of the Kaimai Range. Compare with colour figs. N13H and N13J.

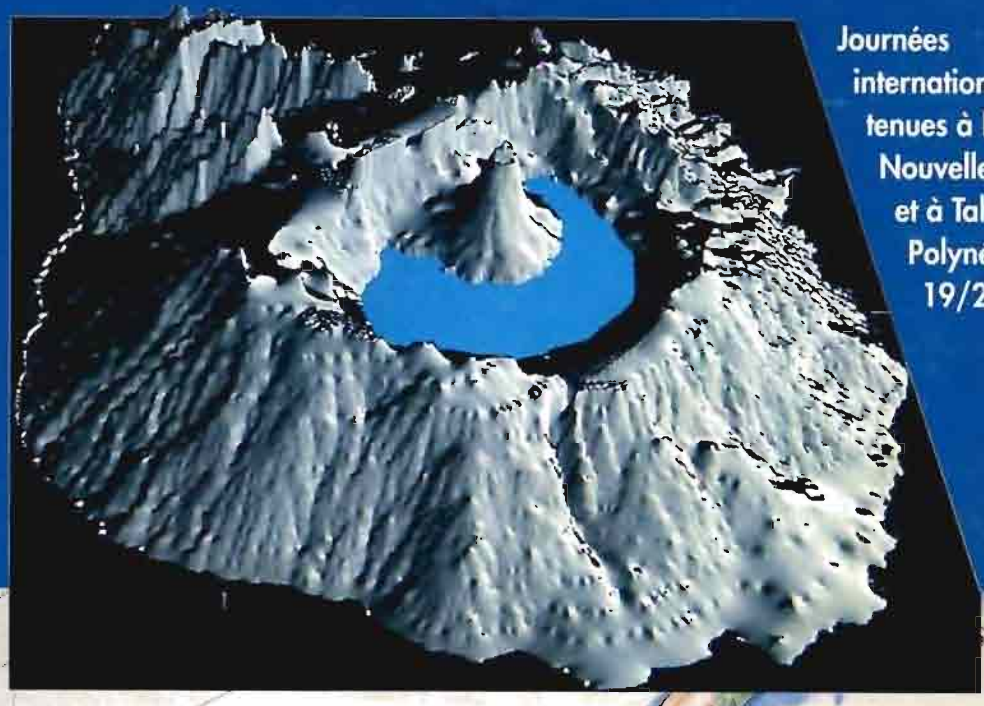
"PIX'ILES 90"

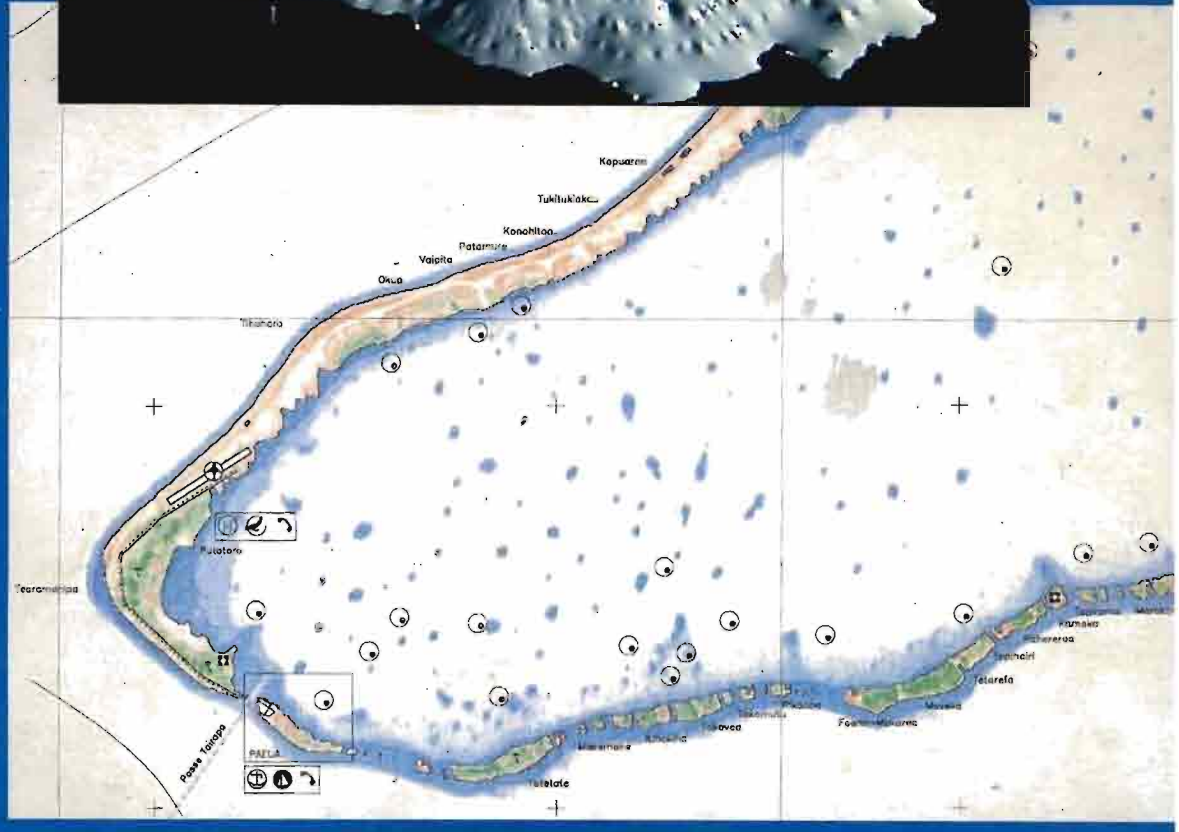
TELEDETECTION ET MILIEUX INSULAIRES DU PACIFIQUE : APPROCHES INTEGREES

REMOTE SENSING AND INSULAR ENVIRONMENTS IN THE PACIFIC : INTEGRATED APPROACHES

International workshop held at Noumea New Caledonia and Tahiti French Polynesia Nov. 19/24 1990

Journées internationales tenues à Nouméa Nouvelle-Calédonie et à Tahiti Polynésie Franç 19/24 nov. 199





ORSTOM

IFREMER

TERRITOIRE DE POLYNESIE FRANÇAISE

"PIX'ILES 90"

Journées internationales tenues à Nouméa - Nouvelle-Calédonie
et à Tahiti - Polynésie Française
19 / 24 novembre 1990

International workshop held at Noumea - New Caledonia
and Tahiti French - Polynesia
November 19 / 24 1990

ORSTOM

IFREMER

Imprimé par le Centre ORSTOM
de Nouméa
Septembre 1992