




See an [animation](#) of the wharf area at Christmas Island

# An advanced GIS-based Resource Management System : The Christmas Island case study

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[\[Introduction\]](#) [\[Overview\]](#) [\[Visualisation\]](#) [\[Integration\]](#) [\[3D\]](#) [\[GIS  
CD-ROM\]](#)

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## 1. Introduction

This paper describes a Geographic Information System (GIS) for Christmas Island. The system has been developed by the Bureau of Resource Sciences (BRS), an agency within the Commonwealth Department of Primary Industries and Energy which analyses, assesses and packages science for the sustainable development of Australia's energy and resource industries.



The Christmas Island Geographic Information System (CIGIS) was developed at the request of the Territories Office, Department of the Environment, Sport and Territories, to assist Government and private organisations with land use management, mining and rehabilitation work. In conjunction with other software it provides a comprehensive management system to assist with the assessment and mining of phosphate resources, nature conservation, environmental management, infrastructure development, and land use planning affecting the Island.



Christmas Island is one of Australia's two Indian Ocean Territories (IOTs), the other being the Cocos (Keeling) Islands. Commonwealth Government policies for the IOTs are directed at implementing mainland conditions and diversifying the local economies. As an Island with unique flora, fauna, marine life and spectacular rainforest, the limited amount of land for mining, urban, commercial (light industrial) and tourist development is being carefully assessed within a multiple and sequential land use context. While the Island's long term economic future is moving towards tourism and related industries, the mining of phosphate continues to add substantially to the economy.



The mining and exporting of bulk rock phosphate from Christmas Island is undertaken by Phosphate Resources Limited (PRL), trading as

## Christmas Island Phosphates.



PRL use the CIGIS under a licensing arrangement with Territories Office. A new mining lease, to be administered under applied Western Australian legislation, is currently being concluded between PRL and the Commonwealth. Inter alia, in this regard BRS:

- provided advice to the Commonwealth and the company on environmental impact and remaining resources of phosphate that could be mined, including the development of a long term mining schedule, and
- recommended the development of a GIS to capture a vast array of historical data concerning stockpiled material required for rehabilitation and other uses.



## 1.1 Christmas Island

Christmas Island, an Australian Territory situated in the Indian Ocean approximately 2600 kilometres north west of Perth and 360 km south of Jakarta, is Australia's only current producer of bulk rock phosphate. The Island is also known for its annual migration of red crabs from the rainforest to the sea to spawn.

Christmas Island is 135 square km in area and approximately 85 square km (63%) is within the Christmas Island National Park. In addition, where terrestrial zones of the Park include the coastline, a marine zone extending 50 metres seaward of the low water mark is included in the Park. The marine zone encompasses approximately 46 km (63%) of the Island's 73 km of coast.



The Island has a diverse multi-cultural community, estimated at around 3,200 persons (November 1996 census), who live harmoniously within an atmosphere of tolerance and respect for the variety of religious faiths and traditions present.

## 1.2 Geography and phosphate deposits

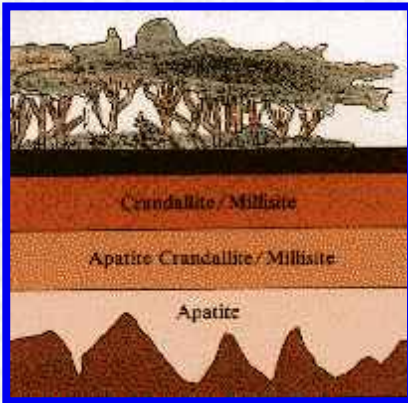
The Island is the tip of an isolated sea mountain and consists of a central plateau 180 - 240m








above sea-level, which descends to the sea in a series of steep slopes and terraces. These terminate in a coastline of limestone cliffs (3 - 45m), except at Flying Fish Cove on the northern end of the Island, which is the only available anchorage.

Geologically the island is a succession of volcanic rocks, limestones and dolomites, with phosphate deposits forming a blanket of variable thickness (avg. 7 - 8m, ranging from 1 - 30m and up to 80m where fault or fissure filling has occurred) over much of the deeply dissected limestone surface. The phosphate deposits consist of:



- an upper phosphate layer (C zone) composed of Al-Fe phosphates,
- an intermediate B zone, which contains variable amounts of C grade and high-grade phosphate, and
- a lower layer (A zone) of high-grade calcium phosphate (apatite —  $\text{Ca}_6(\text{PO}_4)_3(\text{OH}, \text{F}, \text{Cl})$ ), which is directly over the dissected limestone bedrock.


[\[Introduction\]](#) [\[Overview\]](#) [\[Visualisation\]](#) [\[Integration\]](#) [\[3D\]](#) [\[GIS CD-ROM\]](#)

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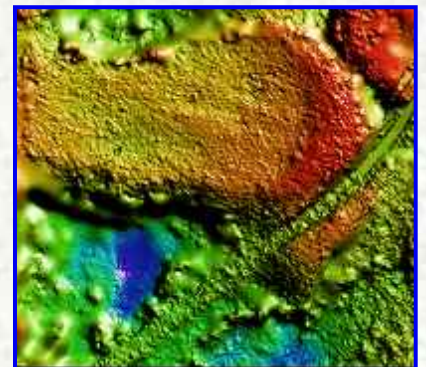
## 2. CIGIS overview






A GIS provides an environment for the management of disparate spatially related digital information. A feature of the CIGIS is the inclusion of detailed soft photogrammetric data, namely orthophotography and a Digital Elevation Model (DEM). An orthophotograph is a computer image of an aerial photograph in which the various distortions due to the landscape and camera lens have been removed, resulting in an accurate background map and/or visualisation for work in the field.


 A GIS is an effective tool for demonstrating and becoming familiar with mining data. It can quickly provide an understanding of the coverage and nature of





available information, which in turn can be reproduced in map form rather than as tables of numbers. Another aid to understanding results is the standard graphics or charting tools, such as pie charts, that are available in most GIS packages. The ability to export results of data queries to a spreadsheet for further analysis or presentation is an added advantage.



The CIGIS, at this point in time, contains :

   detailed colour orthophotography (at a 30cm ground resolution) presented as one hundred and fifty-seven 1km<sup>2</sup> tiles for the whole of the Island,

 a DEM for the whole of the Island, which has one metre 'posts' over all mining leases, township, cleared or regrowth areas, and five metre 'posts' for the remaining areas of the Island which are primary rainforest,

    1:25 000 scale AUSLIG topographic data (roads, buildings, hydrological features etc) for the whole Island,

- ■ ■ ■ ■ 1:1000 scale topographic data for the northeast quarter of the Island, similar to the AUSLIG data but in far greater detail (eg power poles, curbing, individual palm trees etc),
- boundaries of phosphate stockpiles as derived from historical versions of mining plans, and from stereoscopic viewing and digitising onto the orthophotography,
- boundaries of in situ resources as derived from historical mining plans,
- ■ scanned images of mining maps left by previous mining companies,
- ■ ■ photographs of mining plant, stockpiles, rehabilitation sites, and Island scenery,
- ■ ■ a representation of the DEM as a shiny colour drape image for selected areas,
- ■ one metre contours derived from the DEM for selected areas,
- ■ 1:1000 scale Mine Lease boundaries and National Park boundaries,
- survey control data,
- local one metre contour surveys from earlier pinnacle field rehabilitation
- nesting sites of a rare seabird, the Abbott's Booby,
- ■ scans of dyeline maps of vegetation and geology used by Parks Australia North,
- ■ ■ locations of aerial photography flight lines, air photo centres, extents and overlaps, and
- preliminary cadastral boundaries and land ownership data.

The orthophotographs are spatially accurate to between 0.3 metres and 0.5 metres in the northeast area of the Island, where there is an enclosing network of high quality control points. For other areas, the accuracy ranges from sub-metre up to 6 metres depending largely on the proximity of, and enclosure by, aerial photography survey control points. The least accuracy is in the distant and more inaccessible areas of primary rainforest.



Resolution of the orthophotographs is impressive, with acceptable quality down to 1:500 scale. They provide a useful visual backdrop to the vector data. ERMapper® was used for image processing and creation of image backdrops from the DEM and orthophotography.




The CIGIS is currently installed at four separate sites with data distributed and archived on CD-ROM. The data layers can be viewed and manipulated on PC using the software package ArcView®. This package facilitates the direct import of various file formats, in particular those from Computer Aided Drafting (CAD) systems. MapInfo® format is also available on the CD-ROM. The CIGIS is supported with a comprehensive user guide.

In the future it is envisaged that the CIGIS will be expanded to support databases for :



- scheduling areas for rehabilitation,
- drilling of stockpiles and in situ resources
- costing of ore haulage options on the road system,
- town planning and development proposals,
- terrestrial and marine environmental features,
- delineating rainforest and vegetation types,
- heritage and other significant sites, and
- management of the National Park

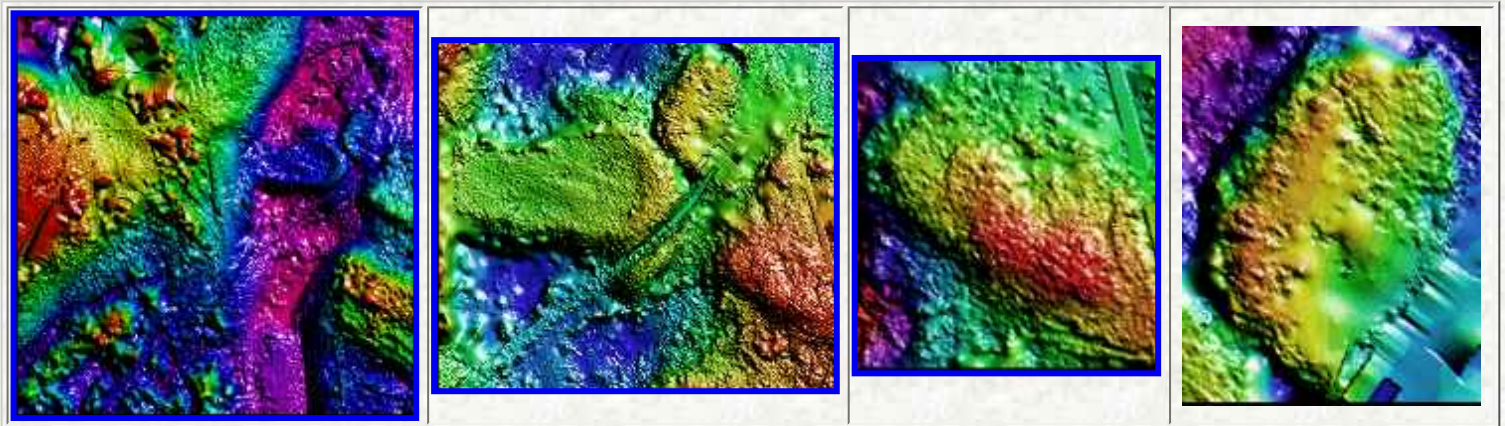
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### 3. Visualisation from orthophotographs and the DEM




 Through the combined use of orthophotographs and the DEM, the CIGIS has become a valuable tool for mining activities, in particular :

- locating phosphate stockpiles heavily camouflaged by vegetation,
- delineating stockpile footprints,
- planning drilling programs,
- identifying areas likely to have in situ resources/reserves,
- tracing overgrown tracks and planning site access,
- separating waste stockpiles from ore on the basis of regrowth vegetation,
- selecting mining methods for different areas, and
- calculating stockpile volumes.



The CIGIS could provide a common spatial data platform for a range of other activities and functions on the Island including management of the onshore and offshore environments, town planning, tourism, road transport and communications facilities.

[\[Introduction\]](#) [\[Overview\]](#) [\[Visualisation\]](#) [\[Integration\]](#) [\[3D\]](#) [\[GIS CD-ROM\]](#)

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### 4. Integration of old maps/data with new survey information

With the CIGIS, multiple projections, local mining grids (16 in total), digital data from old 9 track tape archives, various CAD systems, dyeline maps and aerial photography have been brought together in the one consistent overlay structure. In a related project a differential GPS system has been developed to output data directly in the co-ordinate system used by the CIGIS and in a format suitable for mining software systems such as Surpac2000®.




In the past, integration of datasets was a labour intensive manual task on a light table. This can now be carried out efficiently using PCs. The local mine grids, three types of projections, imperial and metric mapping data, have been translated to a unifying metric grid.

With the CIGIS the elements of any coverage can be related to those of another. These include 'distance from', 'contained within', 'overlap' etc. These spatial analysis tools make it possible to :


- determine the locations of phosphate stockpiles relative to roads,
- assess whether stockpiles overlap mining lease boundaries,
- calculate resources in selected groups of stockpiles,
- determine proximity of waste stockpiles (fill) to particular pinnacles areas, and
- estimate void and fill requirements for rehabilitation of old pinnacles fields.

Scenarios can now be modelled using the datasets in combination to present results, which were previously time consuming to construct or simply not feasible to study.

[\[Introduction\]](#) [\[Overview\]](#) [\[Visualisation\]](#) [\[Integration\]](#) [\[3D\]](#) [\[GIS CD-ROM\]](#)

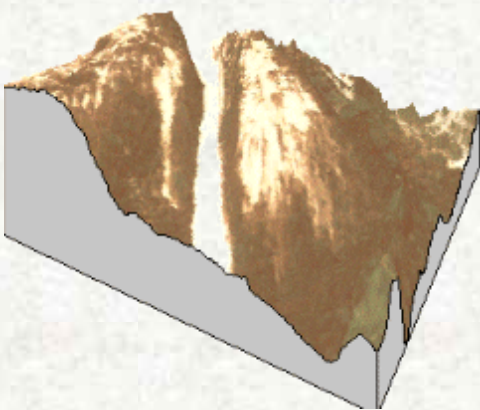
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## 5. 3D visualisations, site photography and video integration

 3D visualisations, site photography and video have been integrated into the CIGIS. These features assist with :-




- induction and training of mine staff,
- discussions and presentations on the mining operations covering mining areas through processing to ship loading,
- visualising how to access and reclaim stockpiles, and
- showing the results of environmental and rehabilitation work.

Photographs, animations, video, spreadsheets or text are integrated into the CIGIS by attaching files to map items using the 'hot link' feature in ArcView®. 3D visualisations are created by 'draping' the orthophotography over the DEM.



There are many providers of 3D visualisation software and a wide range of costs and benefits. At the top of the range, an investment of several hundred thousand dollars is not unusual for dedicated hardware, software and skilled IT staff. Such a set up will allow interactive "fly through" sequences and diverse functionality. At the other end of the price scale are shareware and freeware packages that can be obtained off the Internet — or world wide web. These are less functional and robust but can meet the requirements of many users who only need simple visualisation features. While these low cost package animations can take many hours to generate and write to disk, they are then available for play back at any time.

[\[Introduction\]](#) [\[Overview\]](#) [\[Visualisation\]](#) [\[Integration\]](#) [\[3D\]](#) [\[GIS CD-ROM\]](#)

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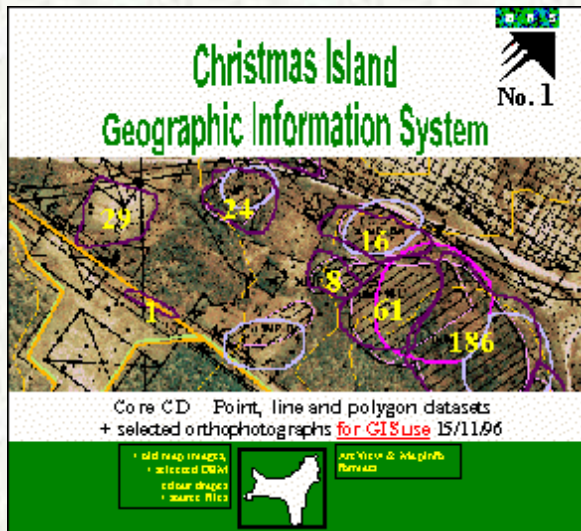
## 6. Preserving information using GIS and CD-ROM




The CIGIS has effectively packaged one hundred years of mining information onto one CD-ROM. Valuable spatial and attribute data are now readily accessible.



The CD-ROM and user manual provide data preservation with multiple copies stored in multiple locations. ArcView® project files are stored on this disc and the data can be browsed and queried as a live GIS. Documentation which describes the data and what has been done to it, is resident in appropriate data directories on the disc. The disc includes source files from which the coverages were created, conversion routines and text files describing the conversion process. The user can always get back to the any original dataset as the CD-ROMs are permanently write protected. A standard directory structure using self-evident directory names has been developed. The storage of documentation and data in multiple formats, including ASCII, should make it possible to read the archive in decades to come.






A CD-ROM GIS archive provides an excellent base to assimilate new data. The quality of the new data is more readily verified by cross correlation with pre-existing data layers.

Similarly, with the creation of an authoritative data store it becomes an easier process to sort earlier versions of data and progressively form up the 'best set'. CD directory structure assists in this process.  The source files are kept in a directory beneath the final dataset and defunct versions are retained only for comparison purposes with other datasets that may be encountered in the future. An example is the boundaries

to the Christmas Island National Park, different versions of which were held by various government agencies.

[\[Introduction\]](#) [\[Overview\]](#) [\[Visualisation\]](#) [\[Integration\]](#) [\[3D\]](#) [\[GIS CD-ROM\]](#)

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## Conclusion

BRS' experience with the CIGIS has shown that packaging of data as a multi-theme GIS CD-ROM product is a cost-effective solution for integrating mining information with data relating to other land use activities.

GIS is now fundamental to the success of many government projects at the State and Federal level where broad decision support and analysis is required.

GIS technology allows users to bring valuable but often poorly used historical data to life. GIS, in a cost effective way, can underpin all aspects of a project from initial data capture, through data verification, integration and analysis to outputting hardcopy products.

[\[Introduction\]](#) [\[Overview\]](#) [\[Visualisation\]](#) [\[Integration\]](#) [\[3D\]](#) [\[GIS CD-ROM\]](#)

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## Acknowledgments

This paper is published with the approval of the Executive Director, Bureau of Resource Sciences, the Territories Office, Department of the Environment, Sport and Territories, and Phosphate Resources

Limited.

























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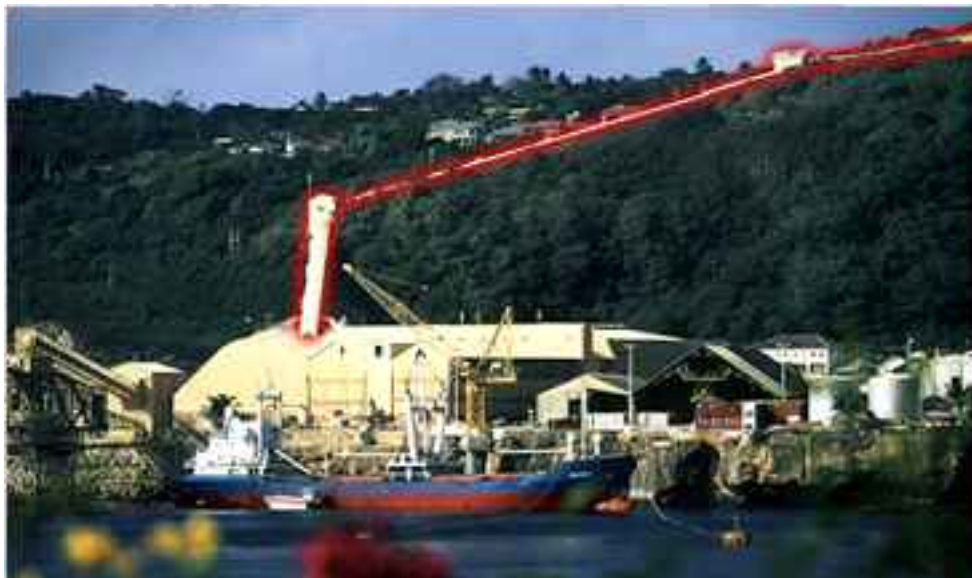




















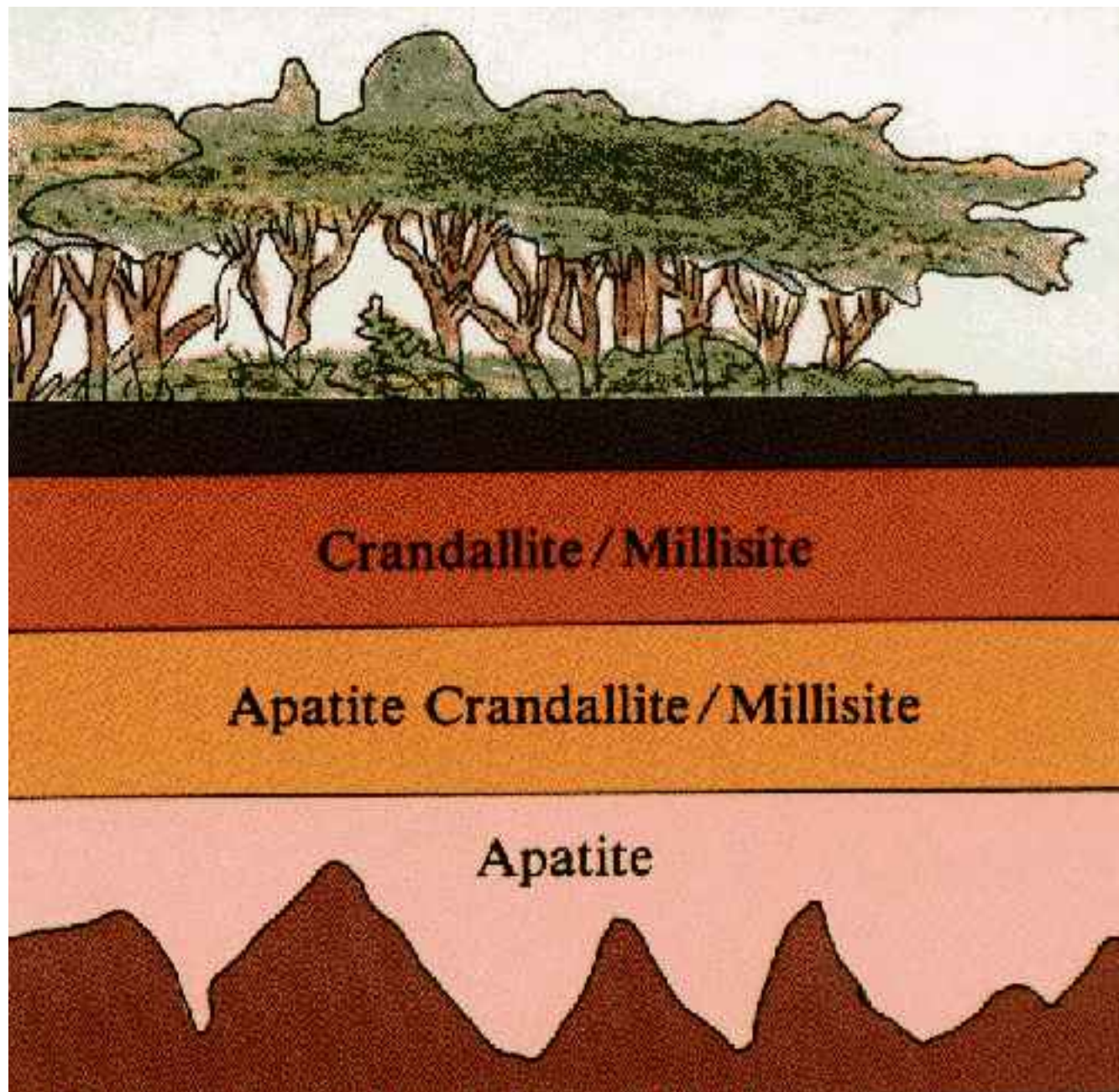


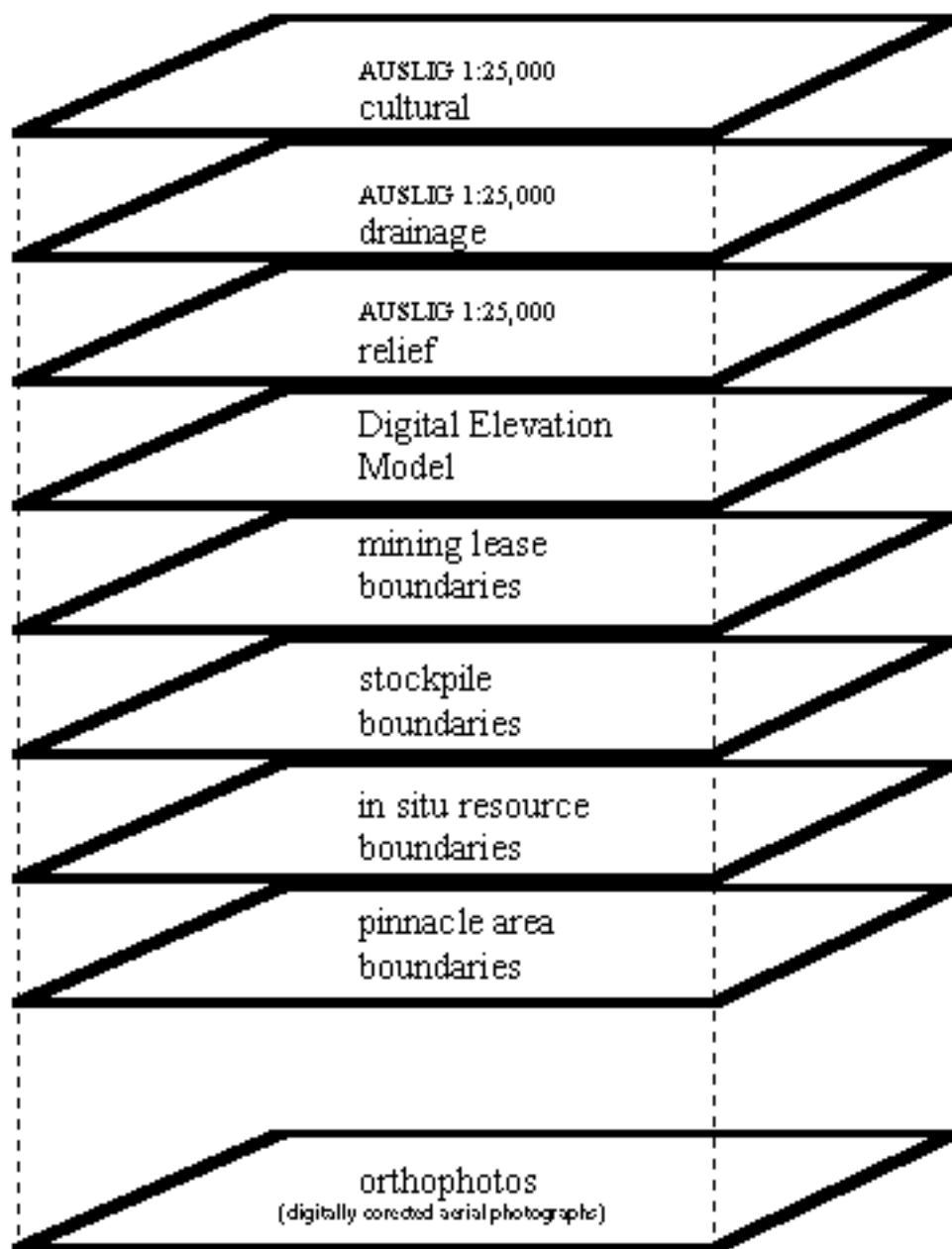
















File Edit View Theme Graphics Window Help

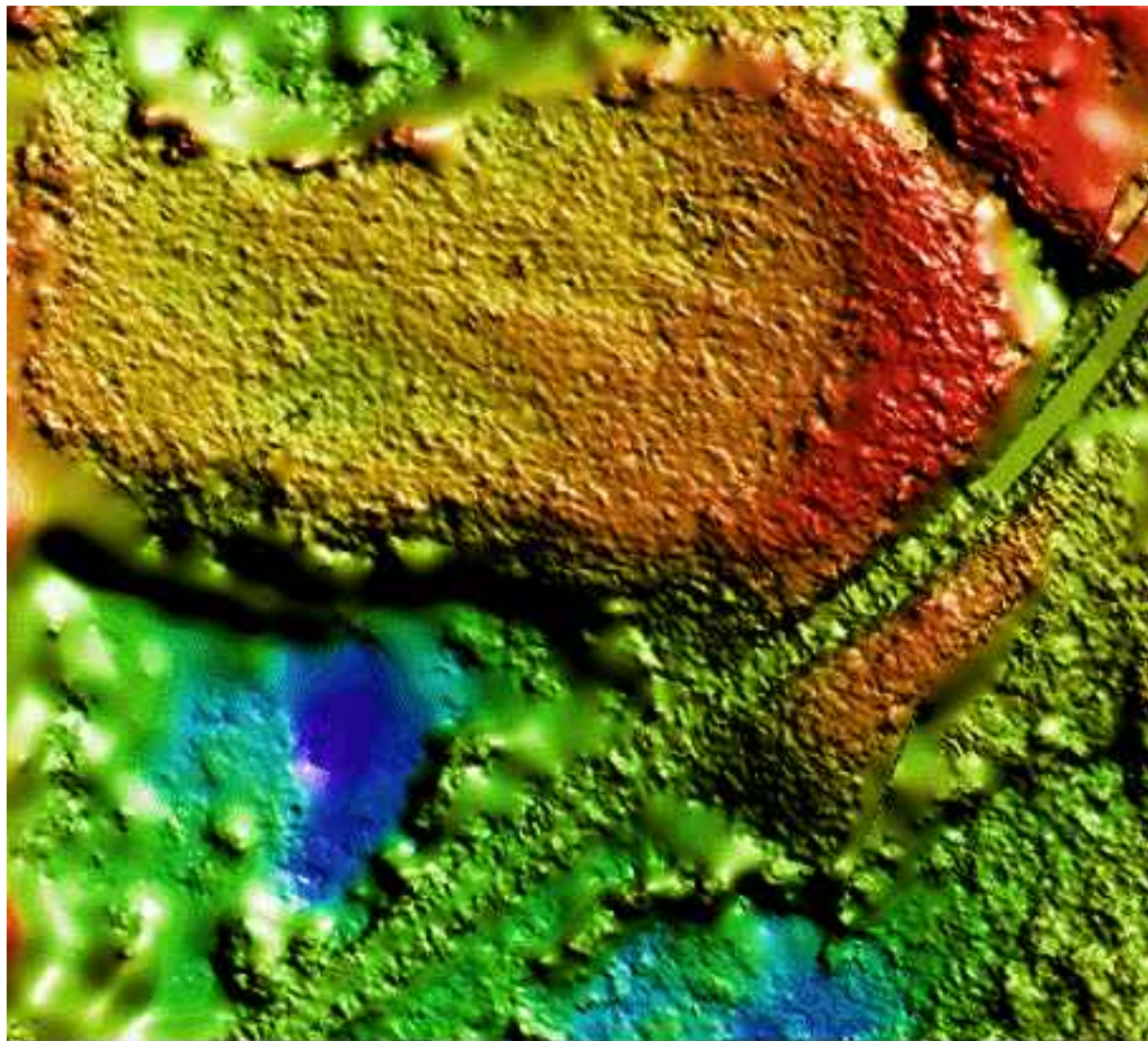


Complex detail

- ☒ 4 km graticule
- ☒ 1 km graticule
- ☒ 1:1000 vegetation boundaries
  - Bottom of Bank
  - Bottom of Cliff
  - Dense Vegetation
  - Group of Palms
  - Medium Vegetation
  - Scattered Vegetation
  - Top of Bank
  - Top of Cliff
- ☒ Contours
  - Text Spot heights
  - Text Contour heights
- ☒ 1:1000 spot heights
  - +
- ☒ 1:1000 roads
  - Kerbed Road
  - Railway
  - Sealed Road
  - Vehicular Track
  - Unsealed Road
- ☒ 1:1000 infrastructure points
  - Buildings
  - Light Pole
  - Aerial/Mast
  - Sign/Pole/Post
  - Power Pole
  - Miscellaneous
- ☒ 1:1000 palm tree
  - +
- ☐ Stockpiles (sourced from old ma
- ☒ Pinnacle field boundaries
- ☒ Mineleaves
- ☒ 1:1000 infrastructure lines
  - Airfield Lighting
  - Building
  - Building Ruins
  - Carpark
  - Conveyor
  - Driveway
  - Fence
  - Manhole
  - Aerial/Mast
  - Path
  - Pipe
  - Power Line
  - Power Pole
  - Retaining Wall
  - Runway/Taxiway
  - Sportground/Park
  - Miscellaneous Structure
  - WALLS
- ☐ Hydraulic features
  - Drain (Bottom Lined)
  - Waterway
  - Coastline
  - Sump (Lined Drain)
  - Tank
  - Water Tank
- ☐ 2000 DEM contours
  - Minor contours
  - Major contours
- ☐ 2007 DEM contours







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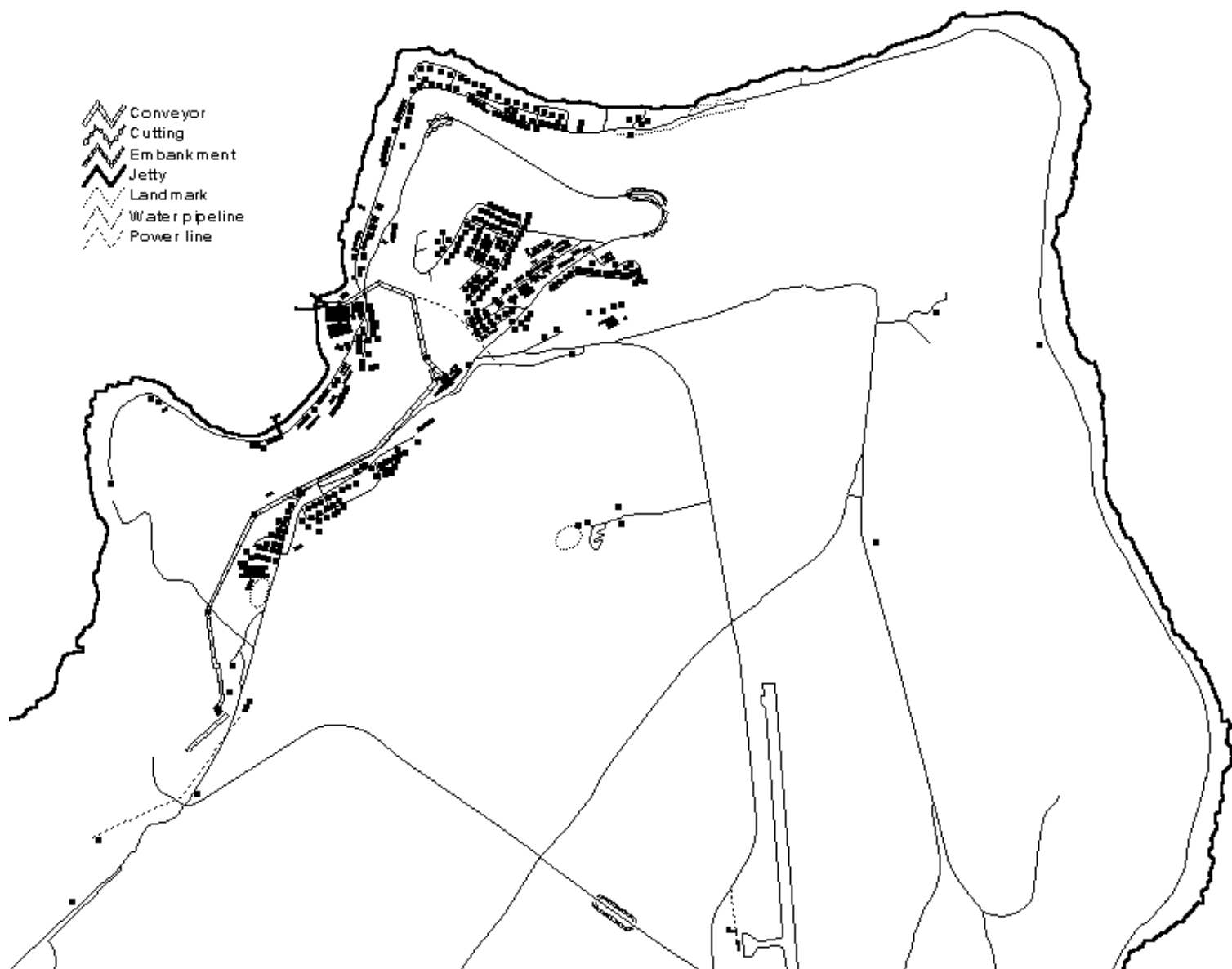




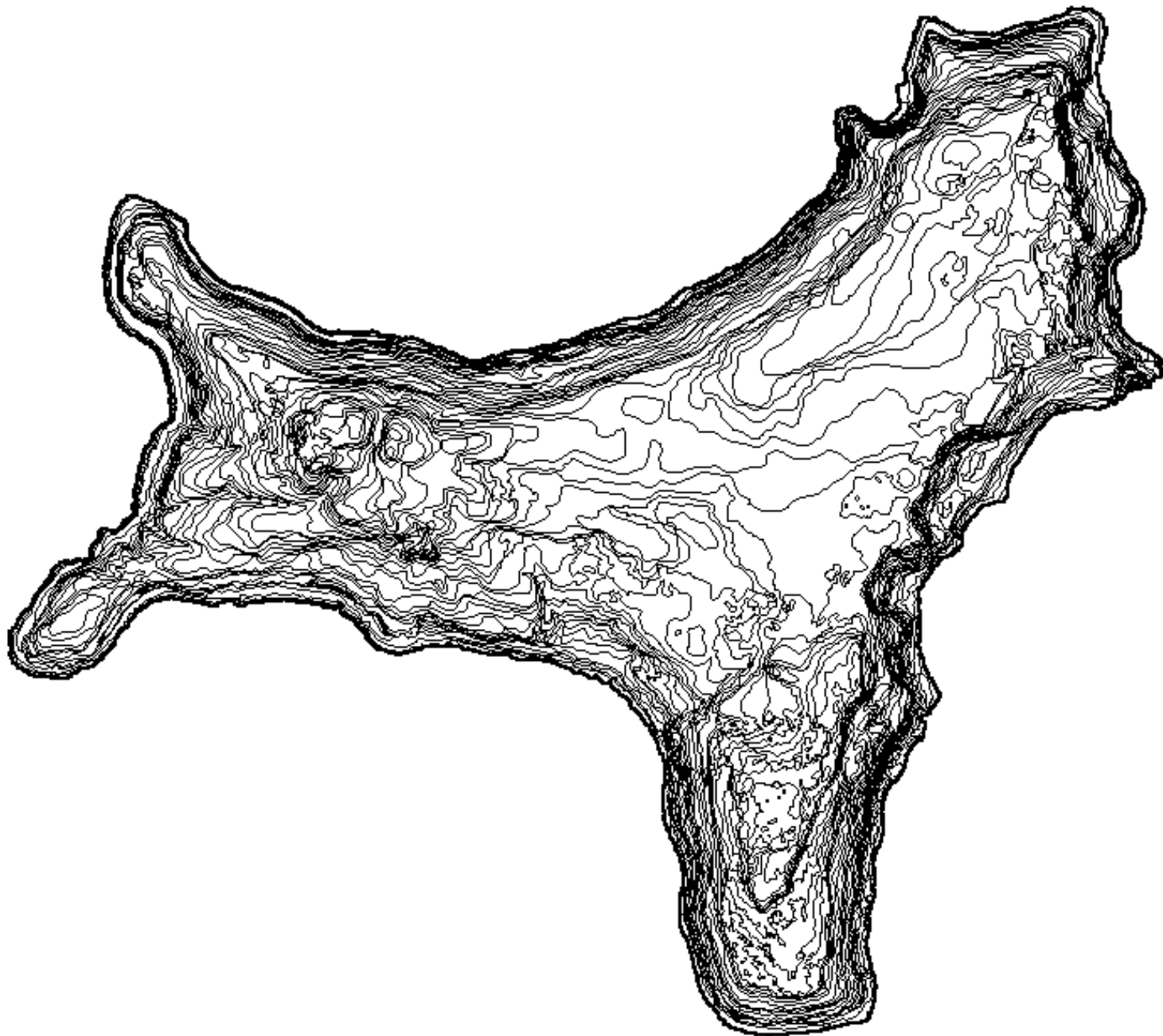






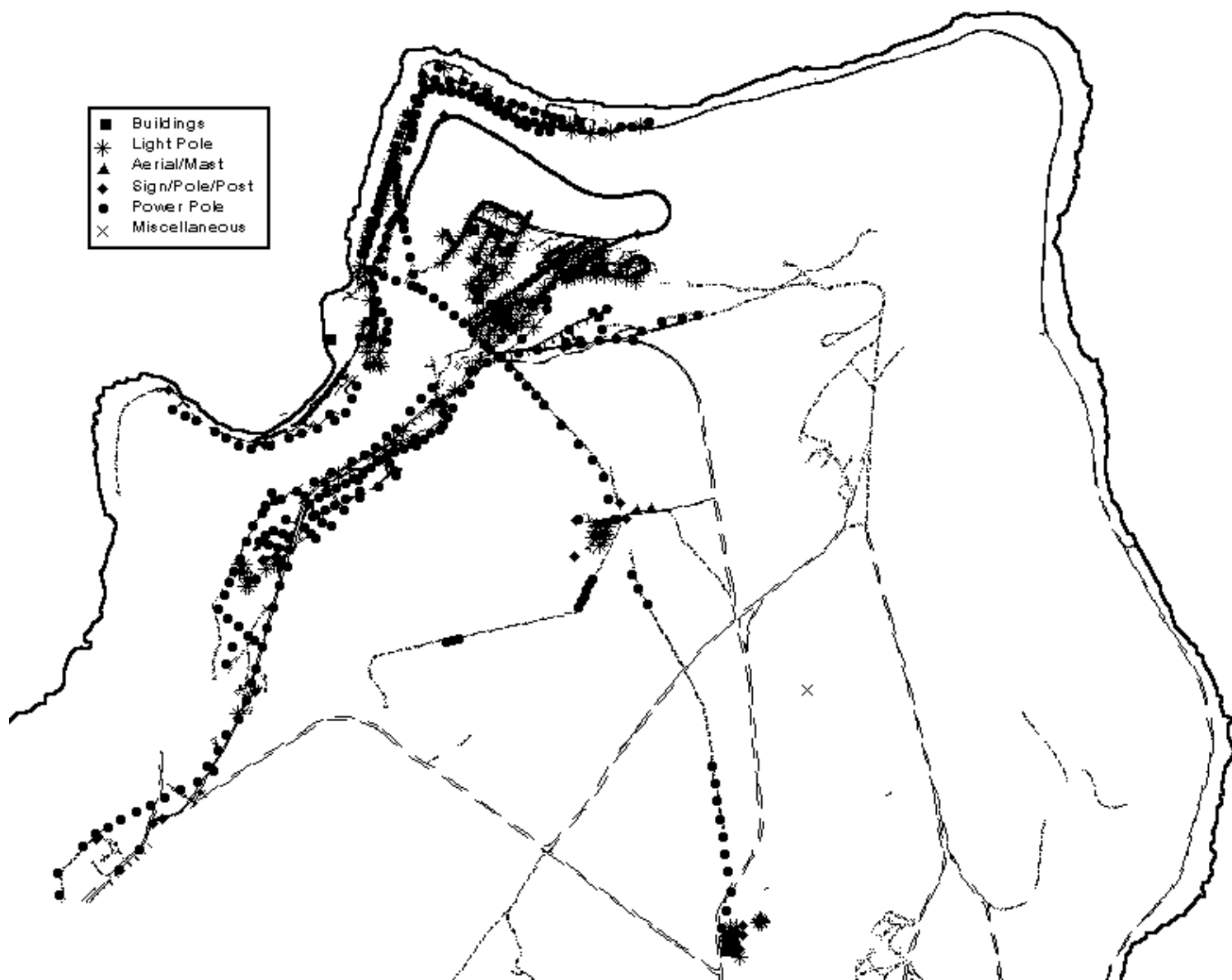


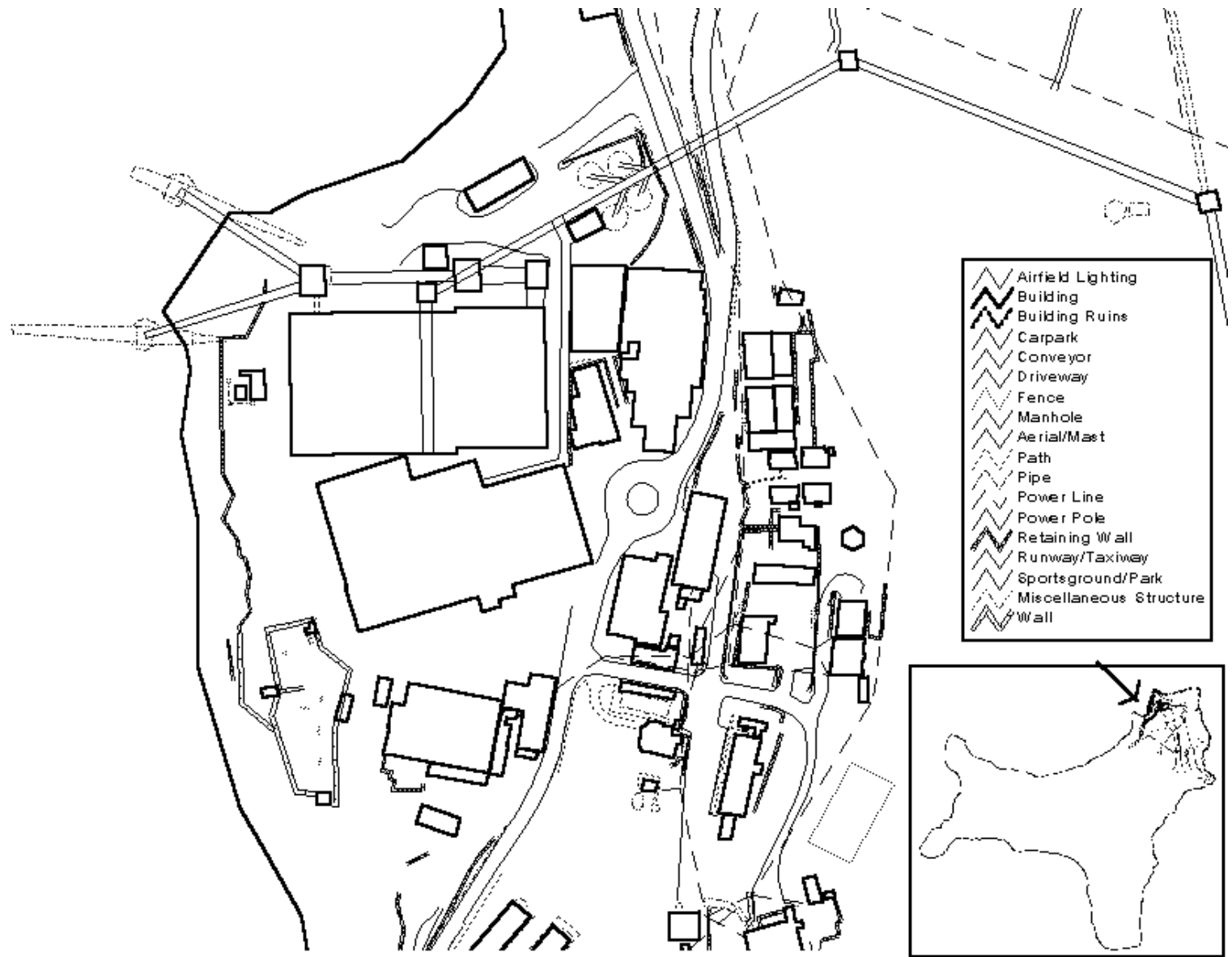






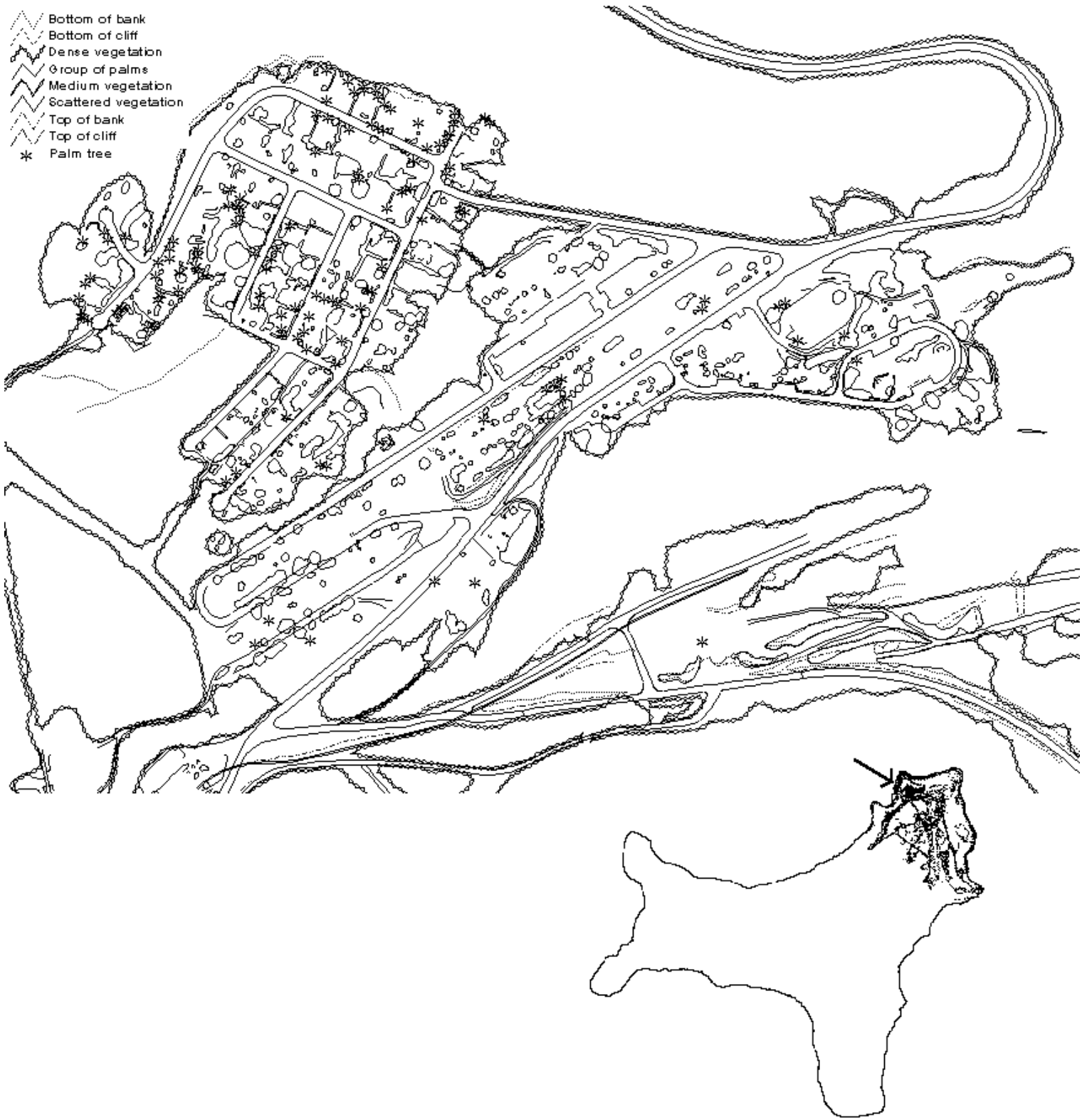








- Bottom of bank
- Bottom of cliff
- Dense vegetation
- Group of palms
- Medium vegetation
- Scattered vegetation
- Top of bank
- Top of cliff
- \* Palm tree





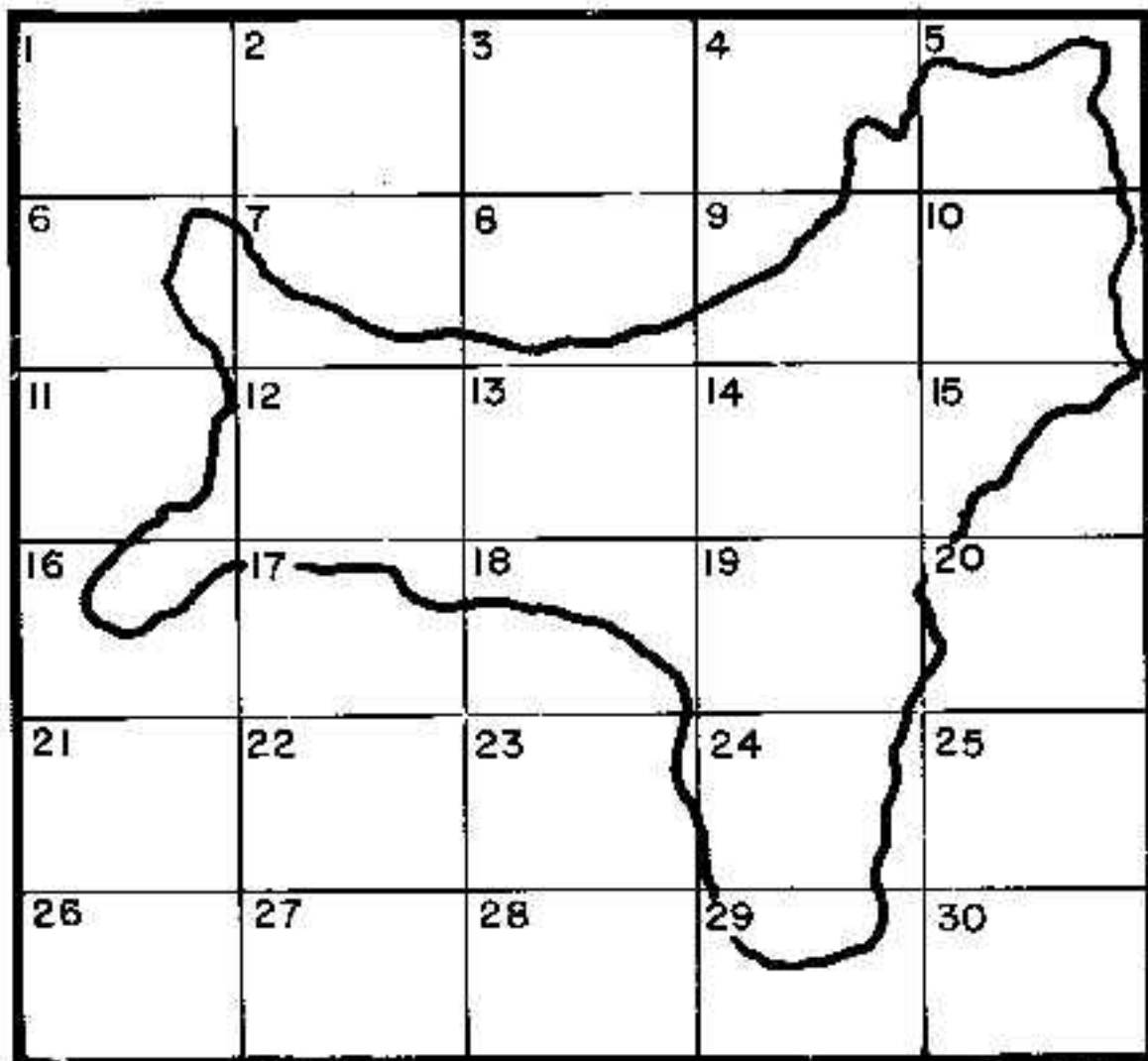


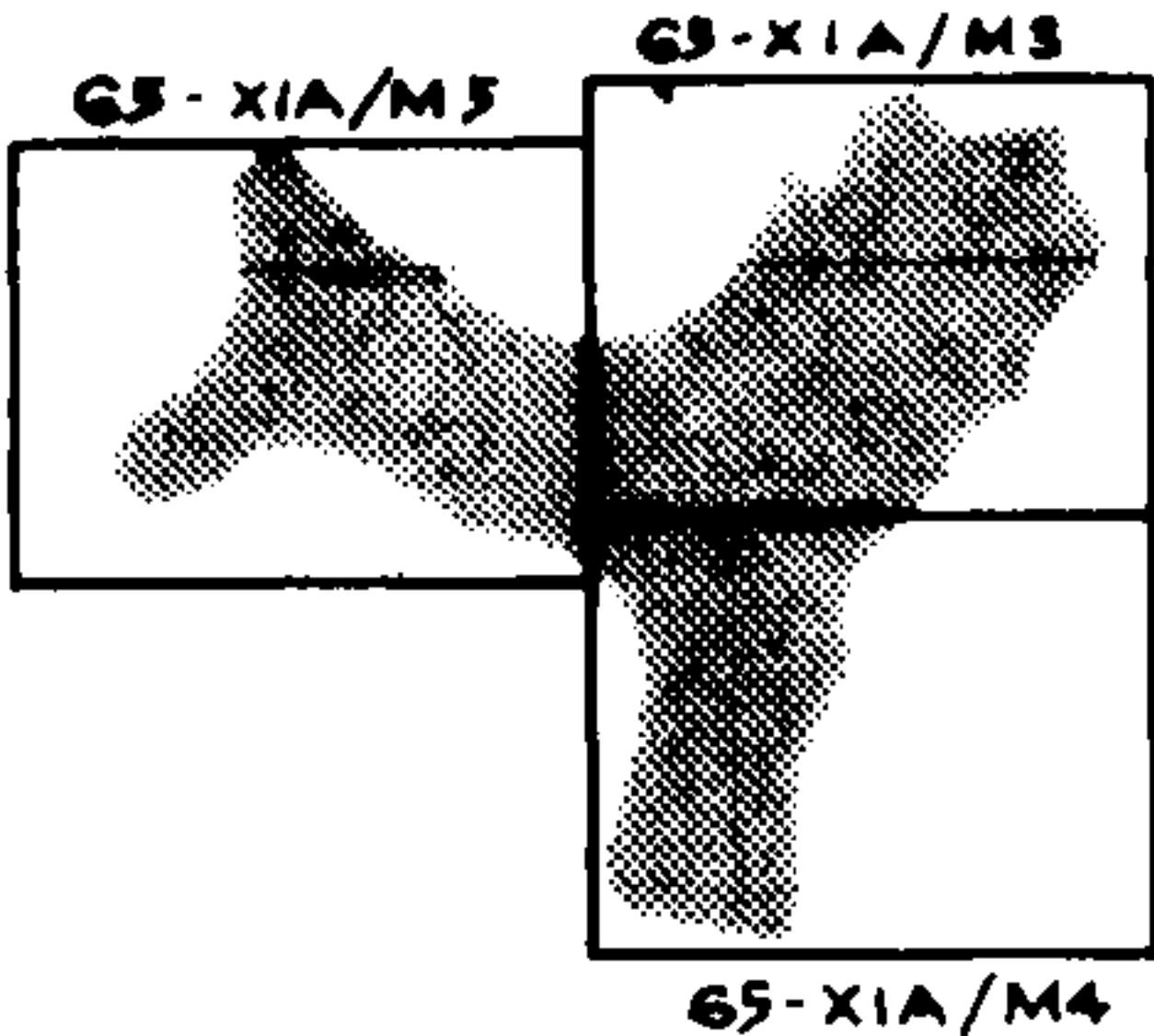




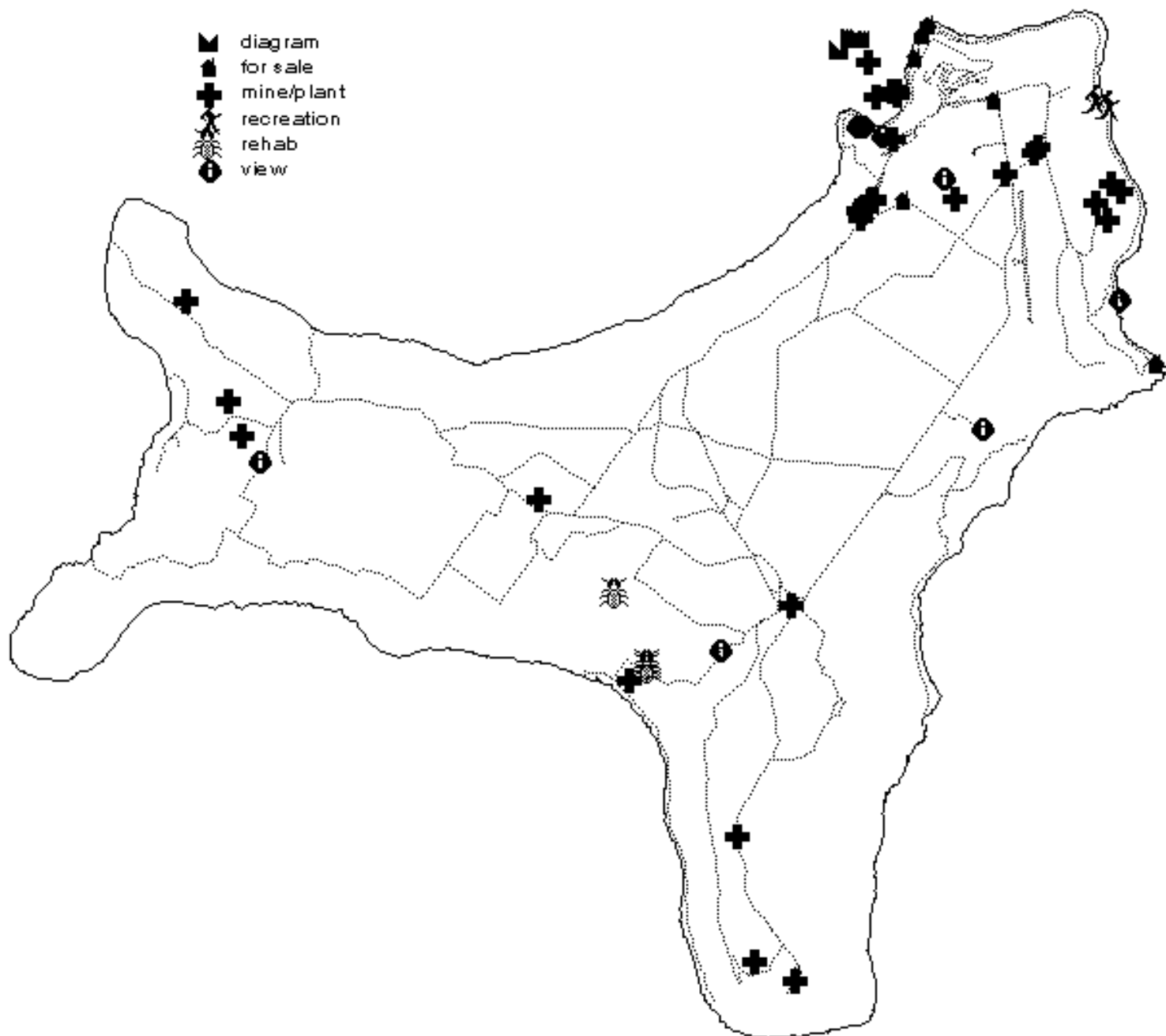
**Confidential data**  
**Christmas Island**  
**Phosphates**

# LOCALITY INDEX











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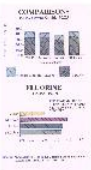
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**burnoff.gif**



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**drumchur.gif**



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**golfhole.gif**



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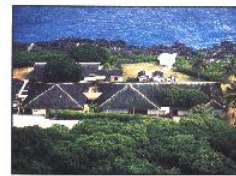
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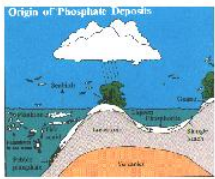
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**oldpower.gif**



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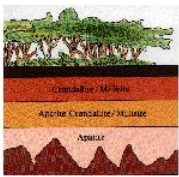
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**viewdown.gif**



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**weststpl.gif**

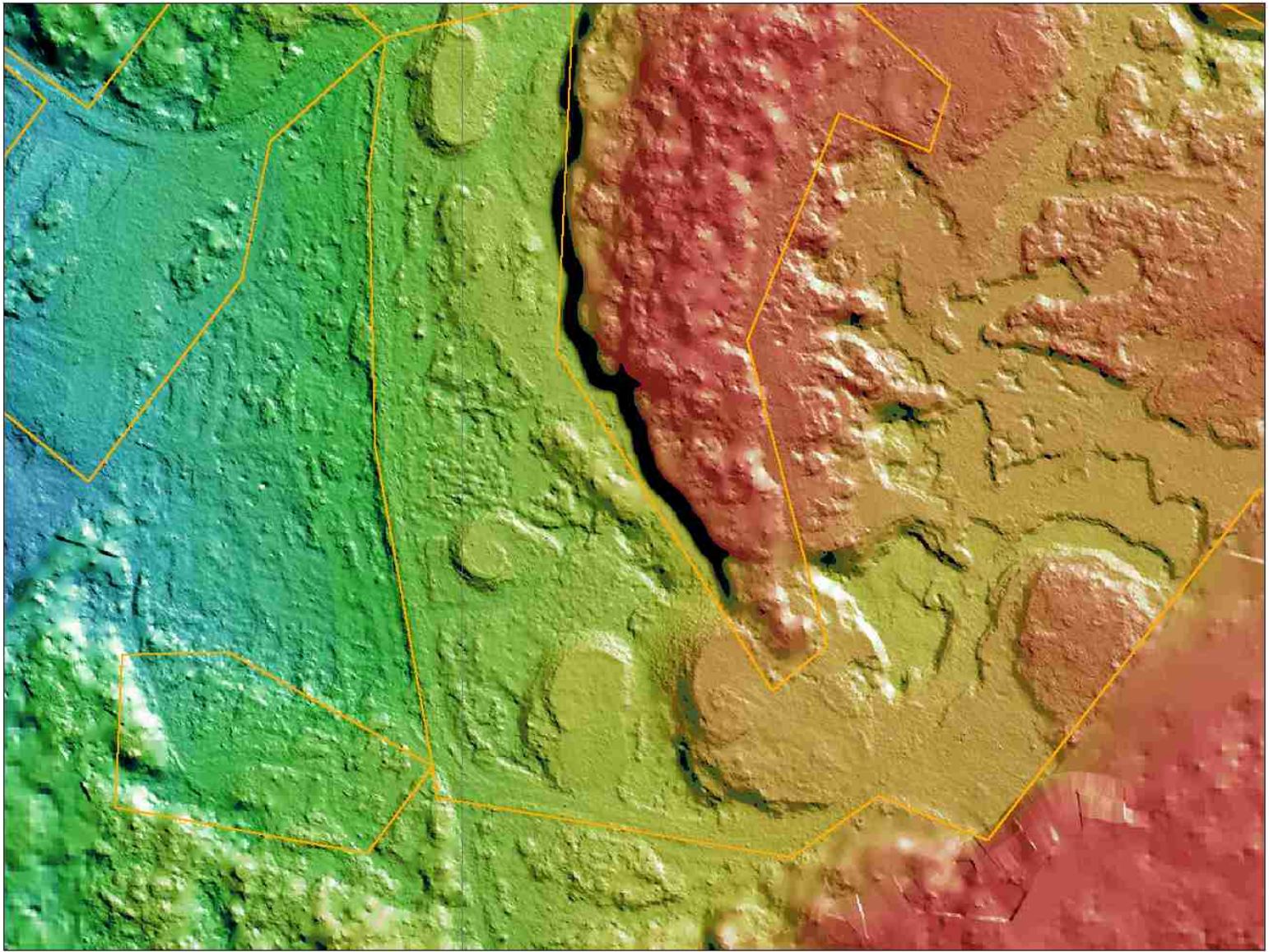


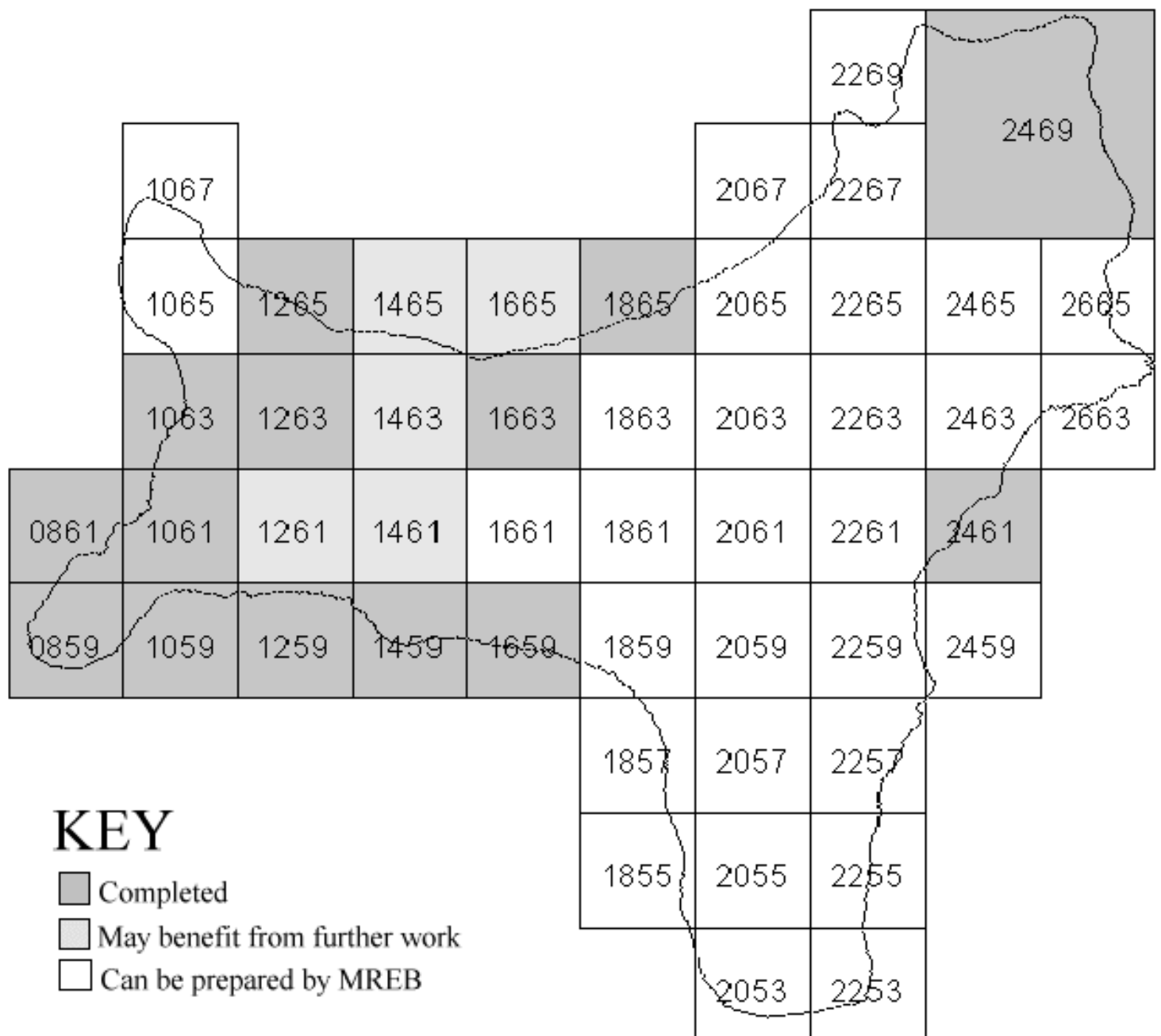
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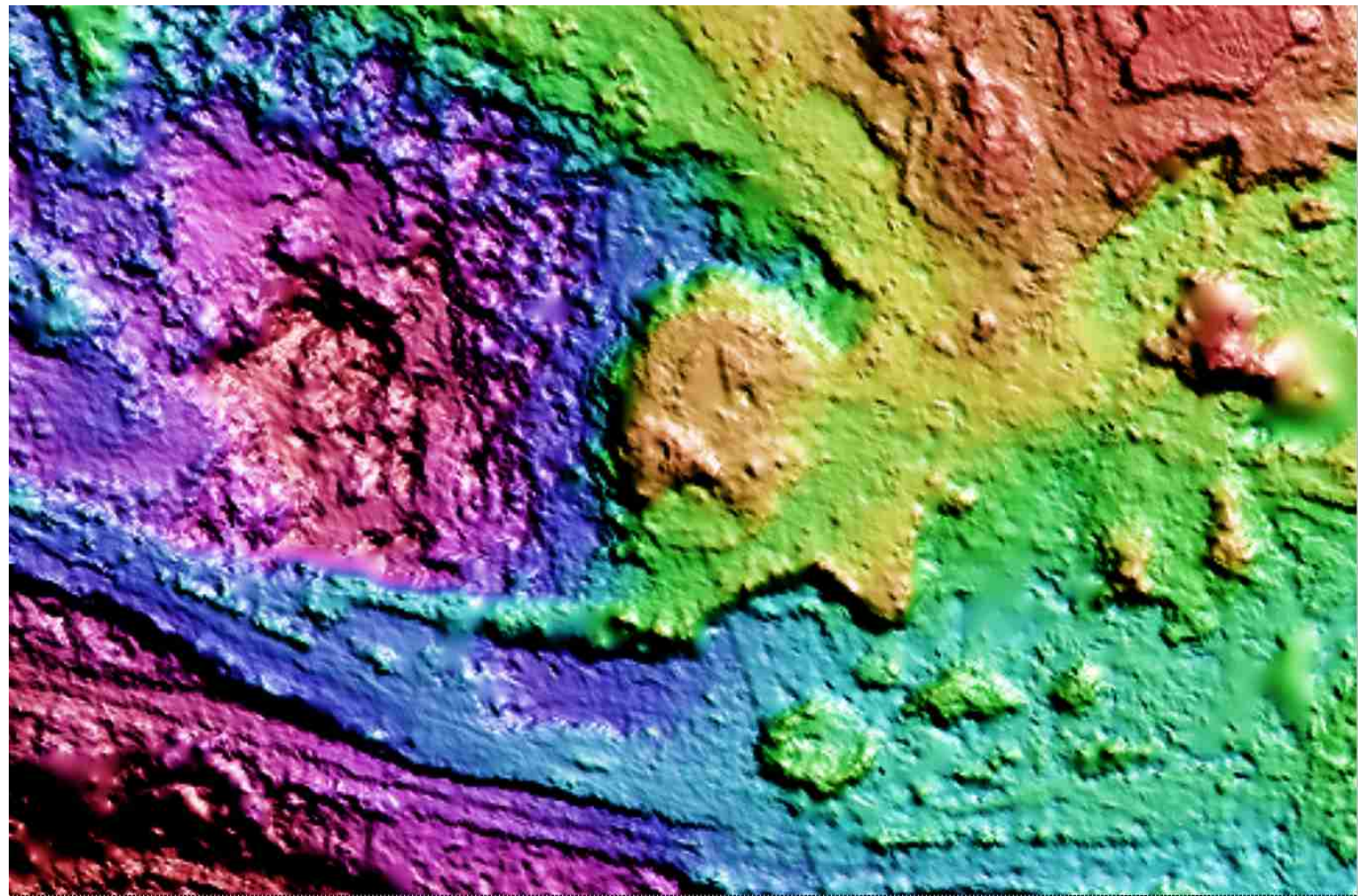
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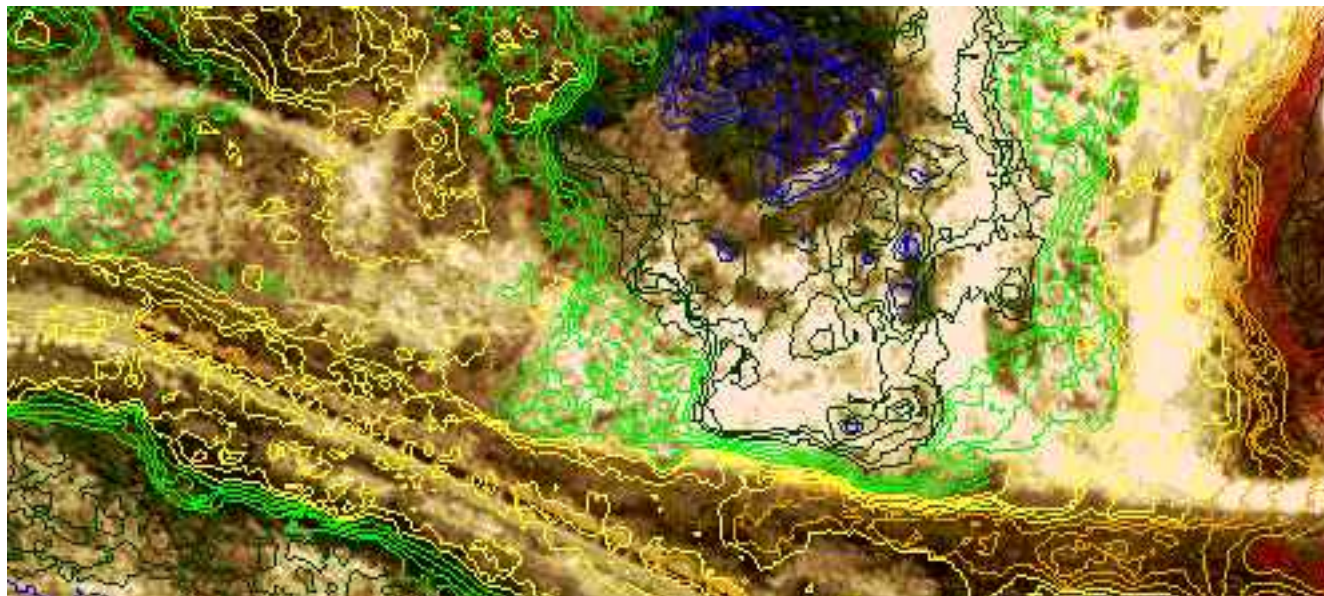






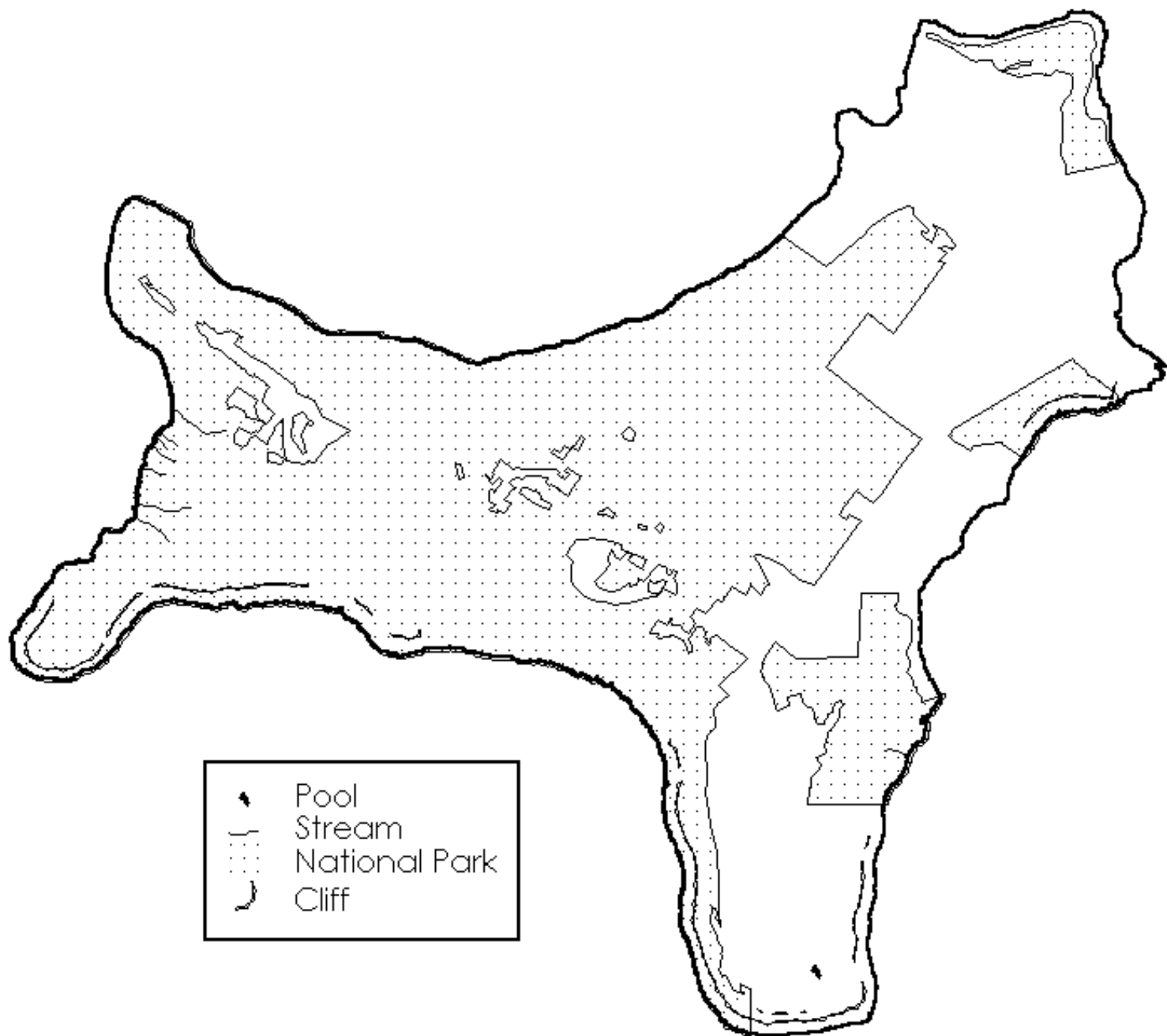


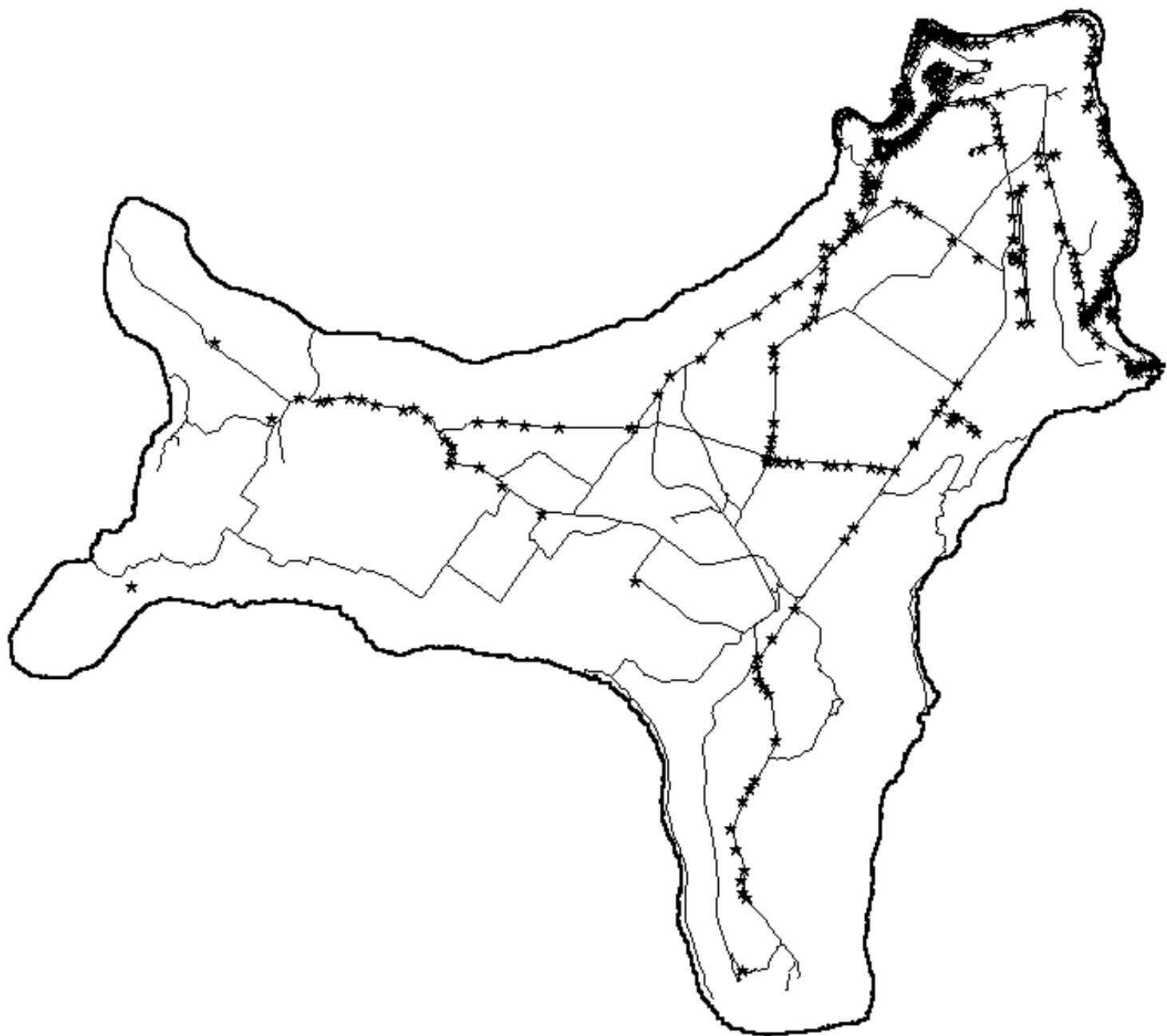


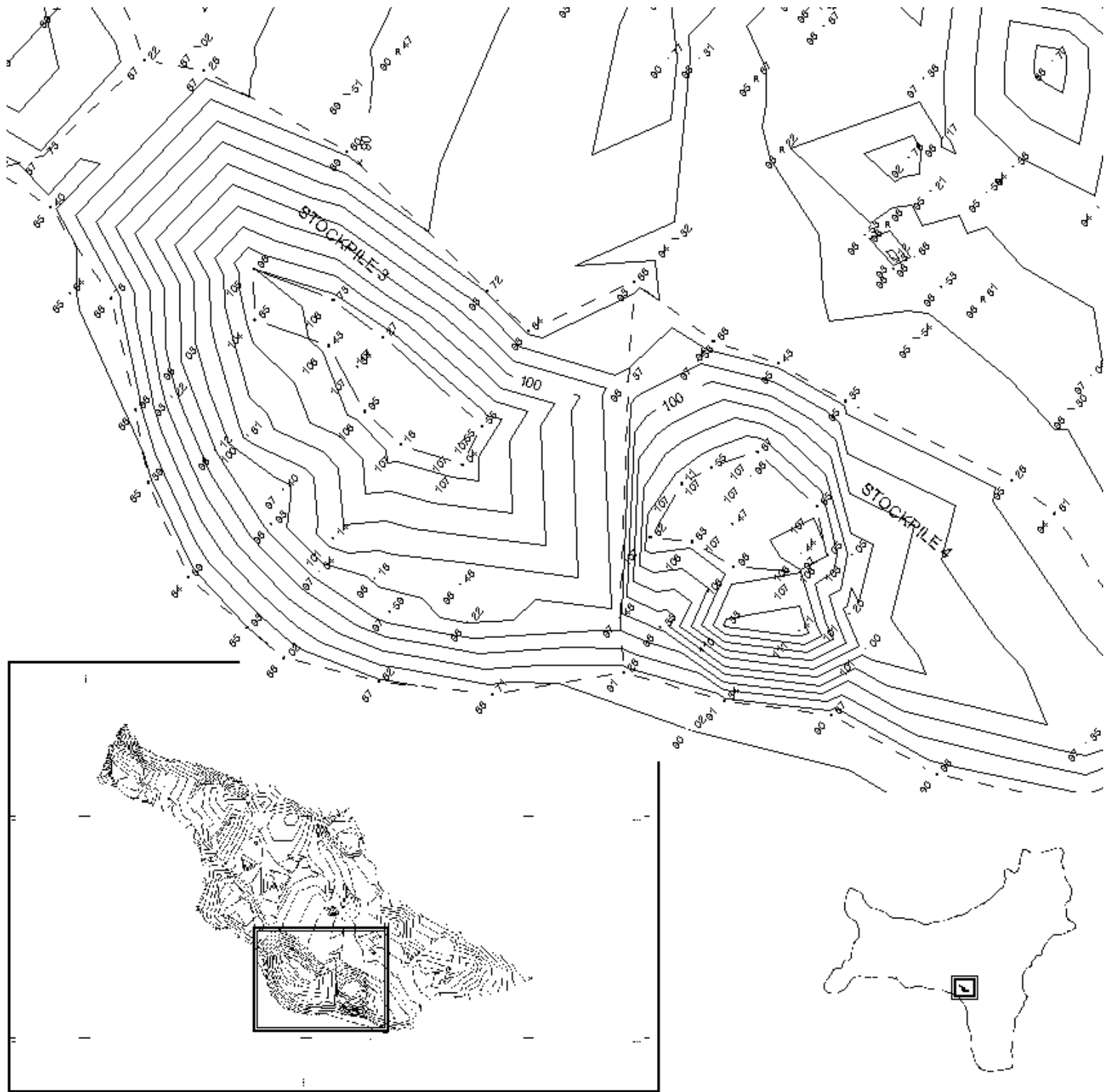




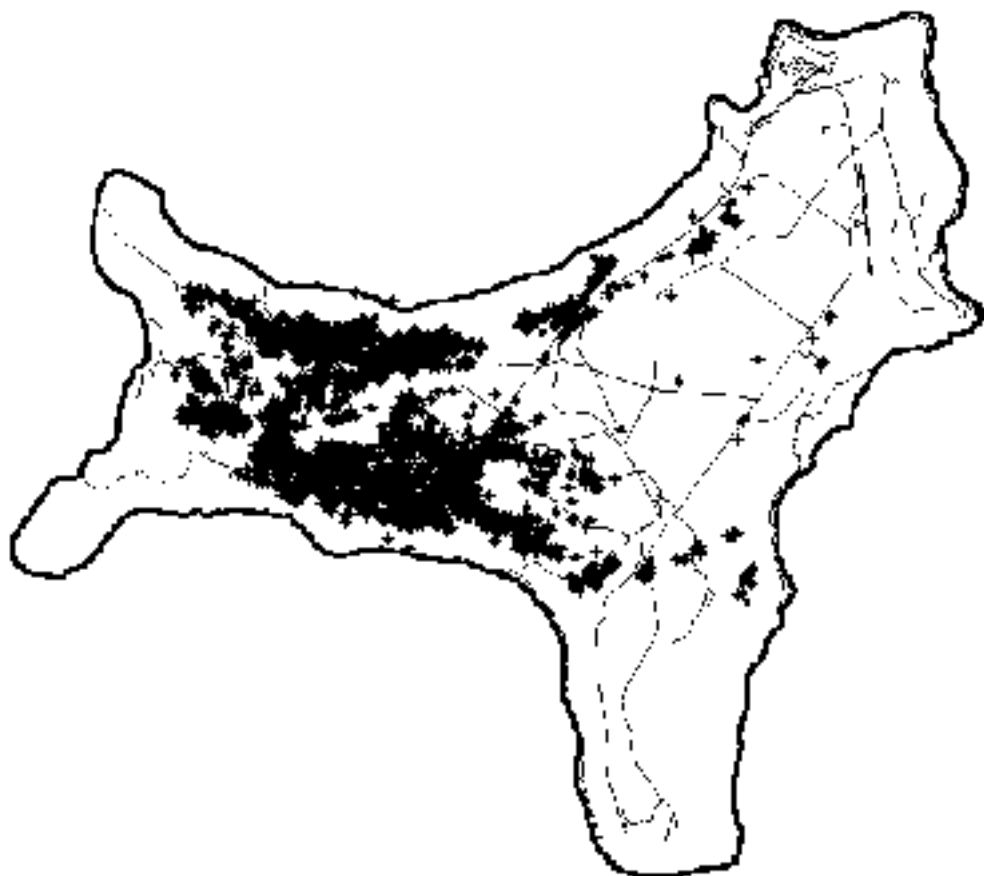






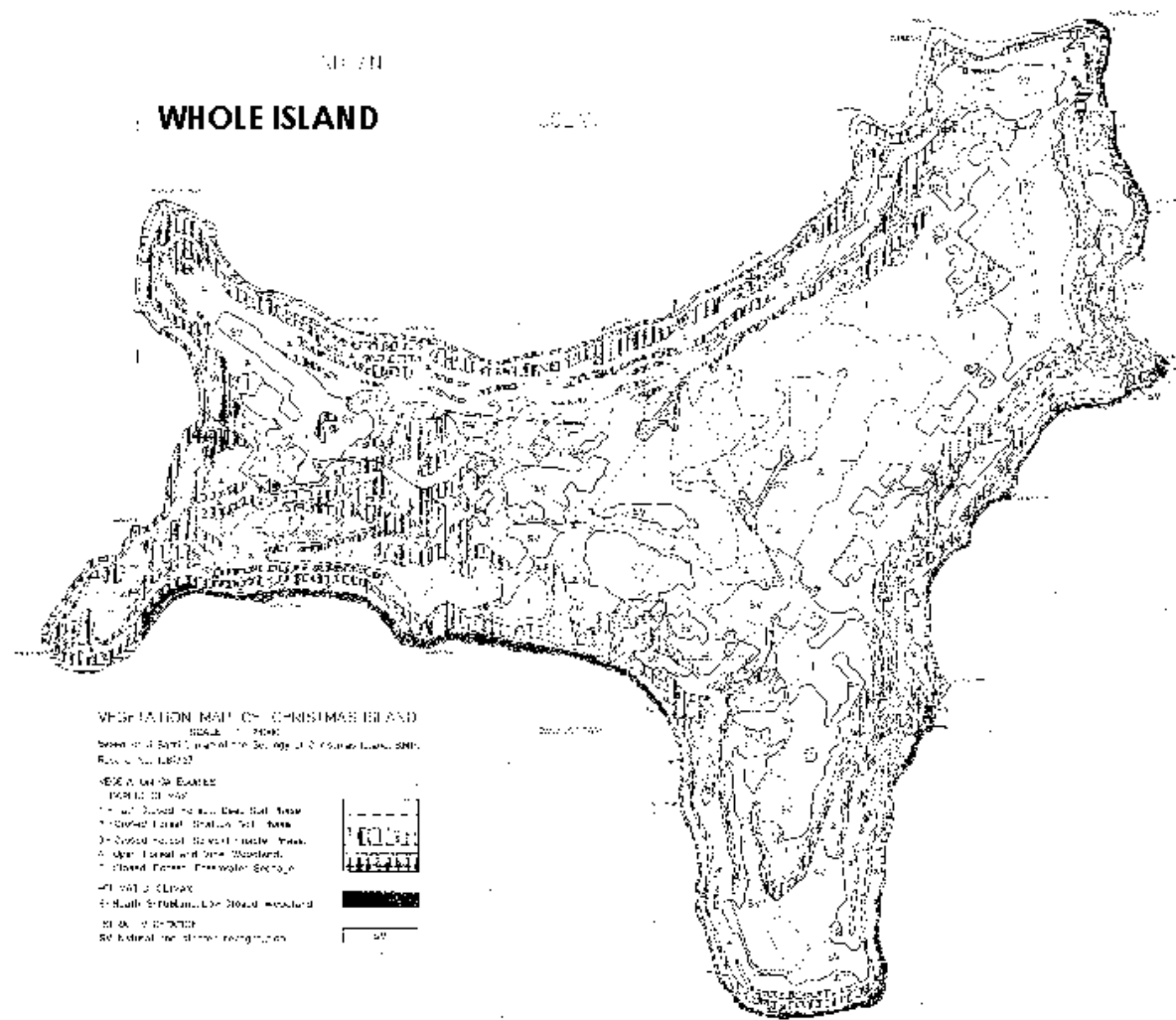






10/7/01

# WHOLE ISLAND



## KEY

### VEGETATION MAP OF CHRISTMAS ISLAND

SCALE 1:25000

Based on J. Barrie's map of the Geology of Christmas Island, BMR.

Record No. 1967/37.

#### VEGETATION CATEGORIES

##### -EDAPHIC CLIMAX

1 - Tall Closed Forest, Deep Soil Phase.

2 - Closed Forest, Shallow Soil Phase.

3 - Closed Forest, Scree/Pinnacle Phase.

4 - Open Forest, and Vine Woodland.

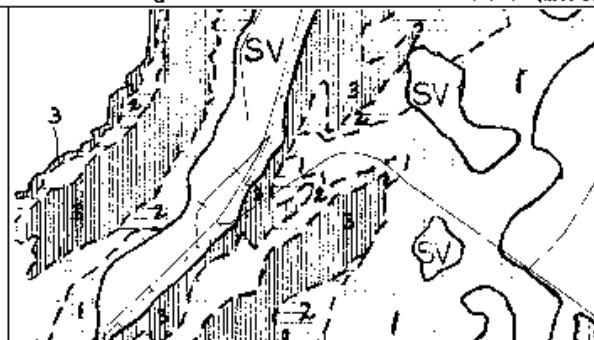
5 - Closed Forest, Freshwater Seepage.

##### -CLIMATIC CLIMAX

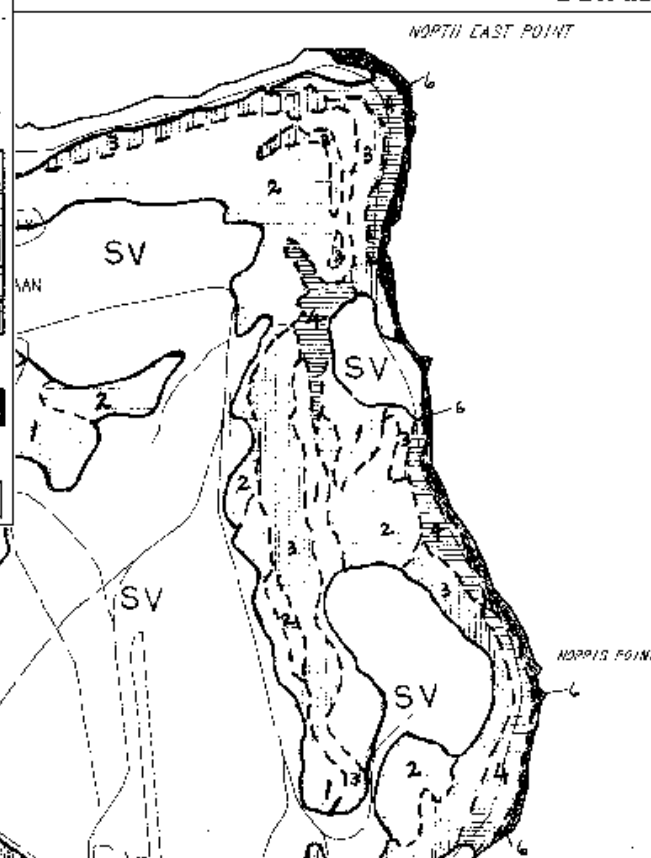
6 - Heath, Shrubland, Low Closed Woodland.

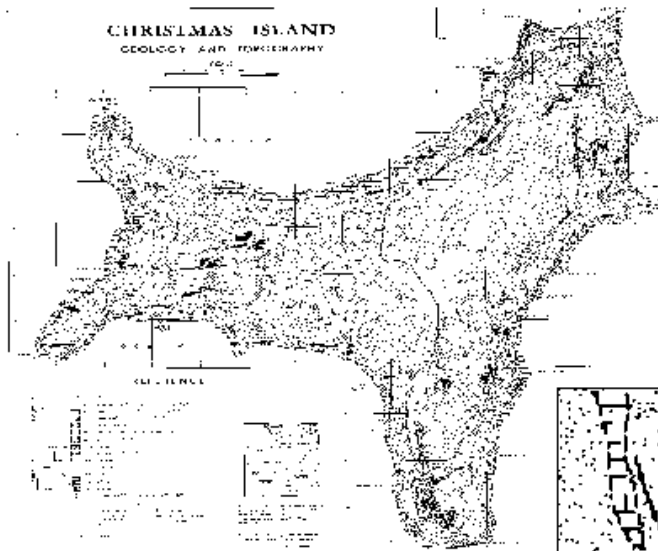
##### -SERAL VEGETATION

SV - Natural and planted revegetation.

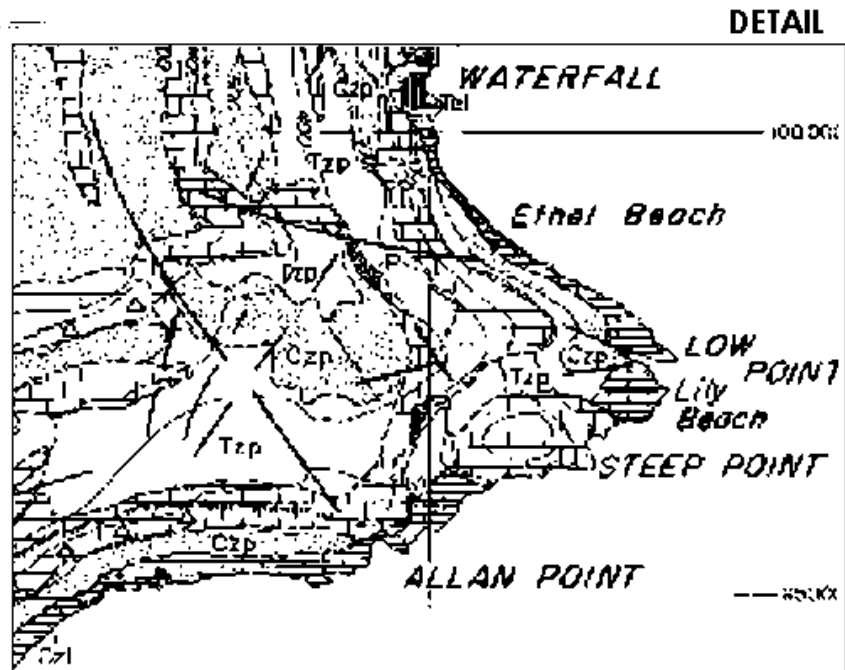


## DETAIL





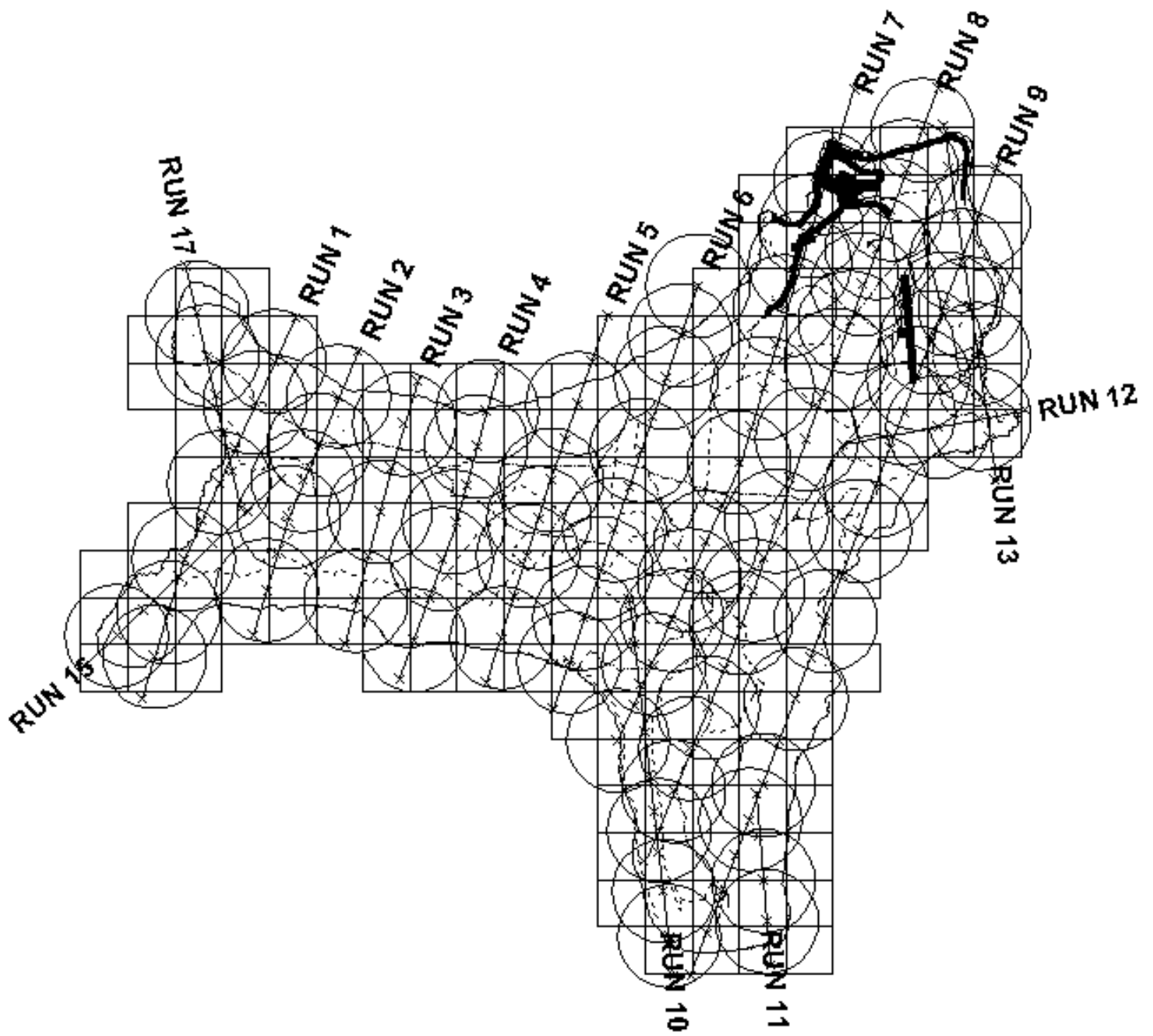
WHOLE ISLAND



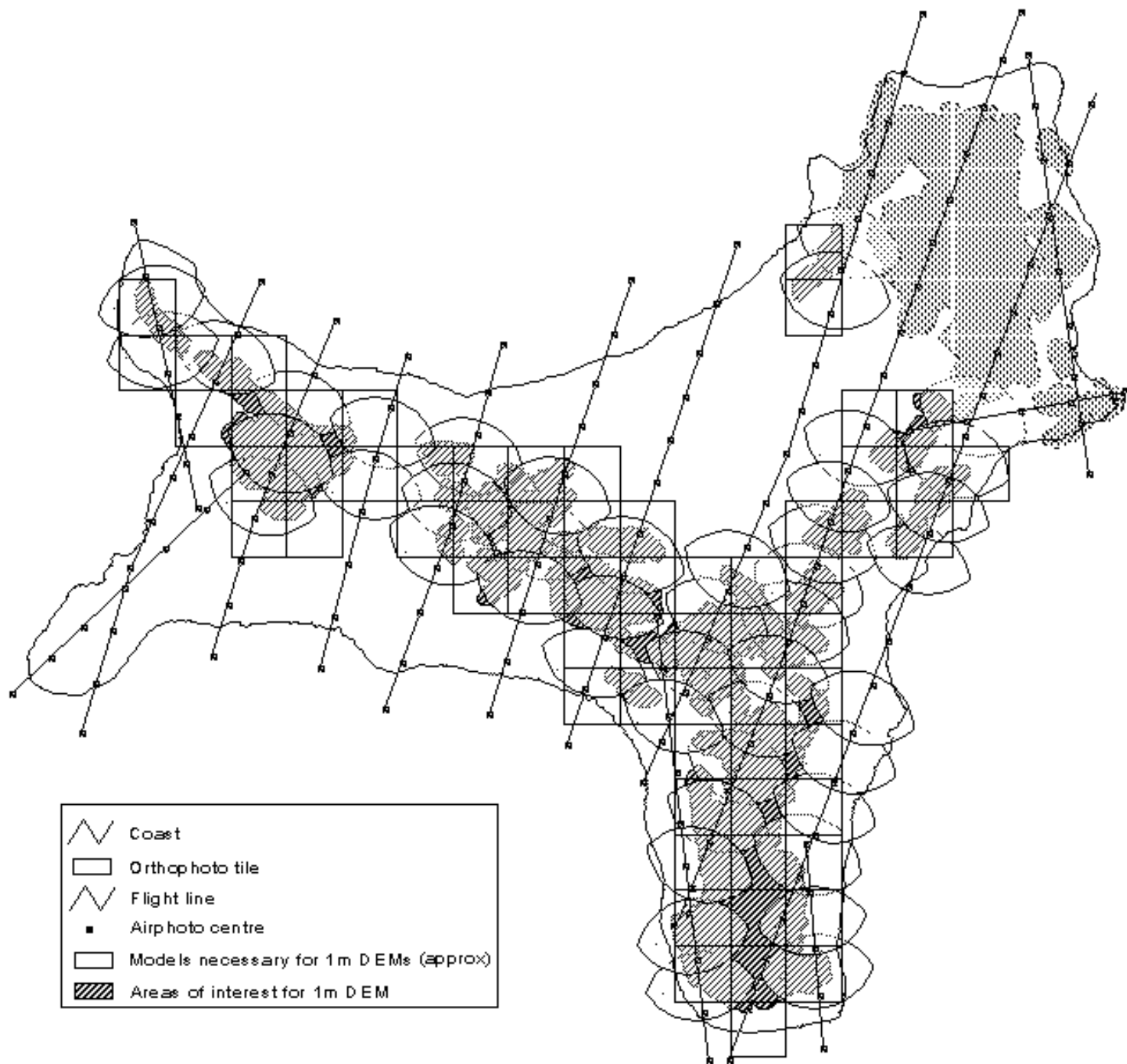
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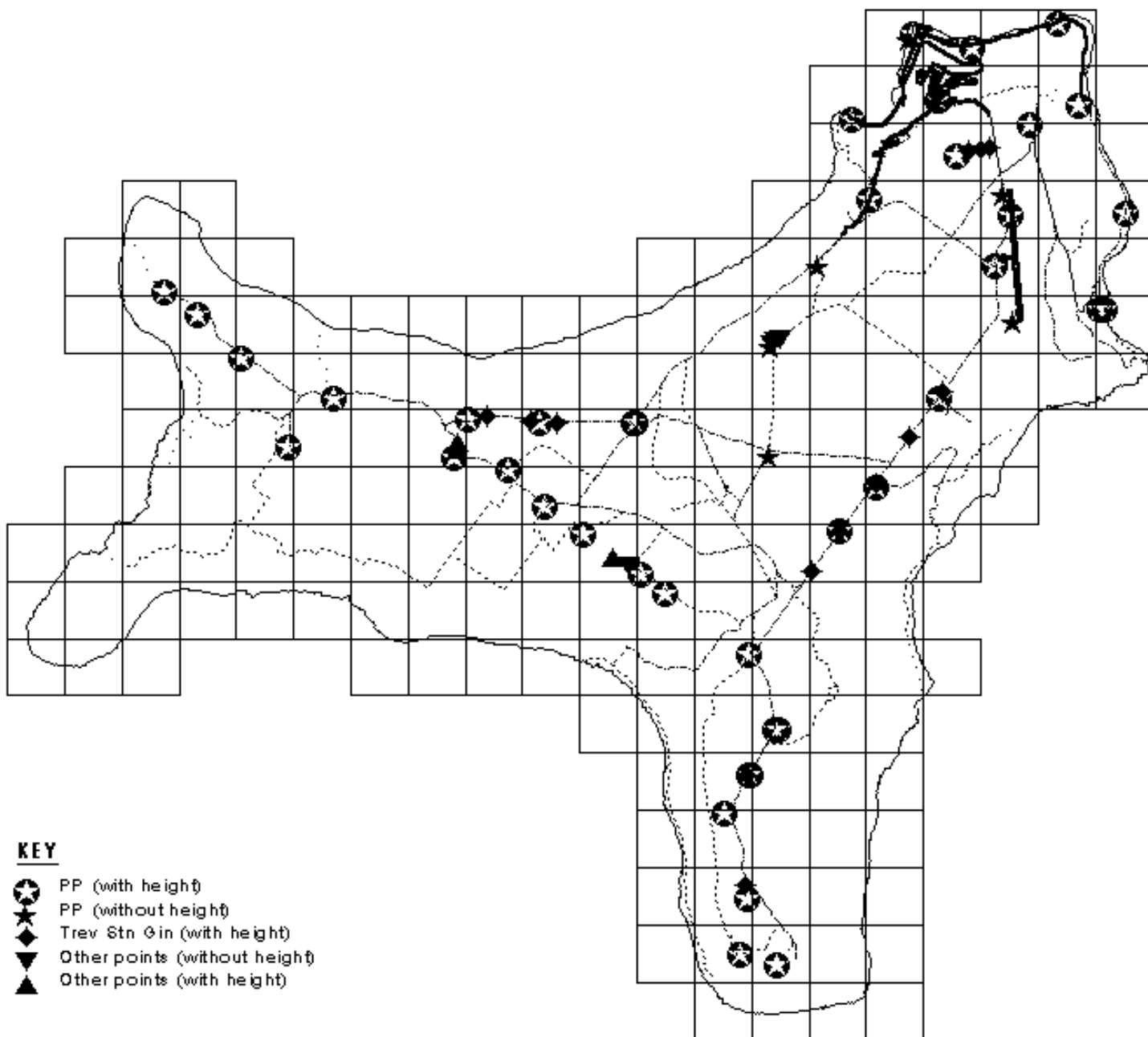
QUATERNARY	Recent		Talus		
			Czp Unconsolidated material - mostly phosphatic soil containing > 20% P <sub>2</sub> O <sub>5</sub>		
			Czl Pellet limestone, contains pellets and pebbles of phosphate rock		
			P Phosphate rock - massive, boulder, and pebble deposits		
			Pv Phosphatised "volcanics"		
			Tzp Pinnacles of limestone with variable amounts of Czp		
	TERTIARY	Miocene or younger		Tz Limestone - undifferentiated	
				Tm(?) Limestone	
		Miocene	f stage		Tml Limestone - undifferentiated
					Tm(f-z) Limestone
e stage				Tme Limestone	
				Tm(e-l) Limestone	
Eocene			Tel Limestone		
			Tb Volcanics - mostly basalt, some tuff, scoria, - undifferentiated		

-----	Geological boundary		Clearing
—————	Aerial photo lineation - supposed fault, fracture		Quarry or development area
—————	Road		Trig station
-----	Track		
+ + + + +	Railway		







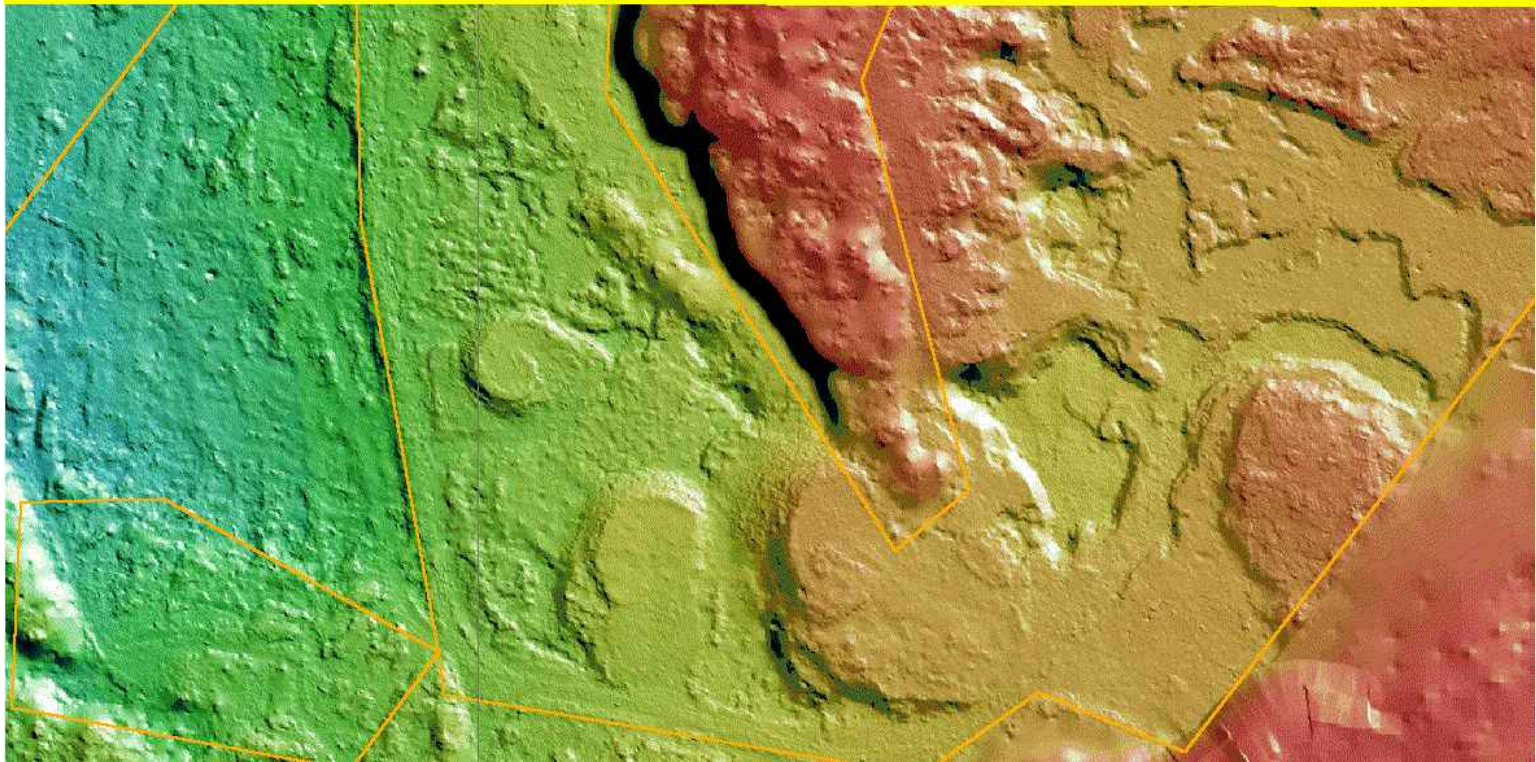




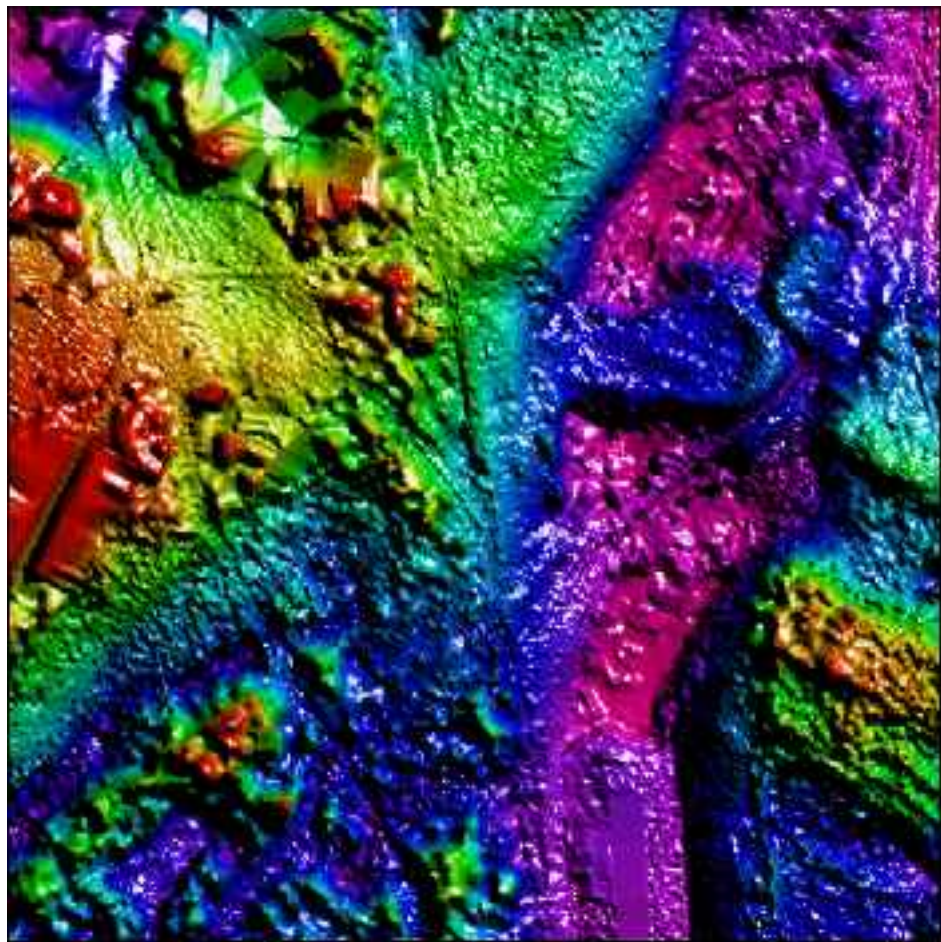


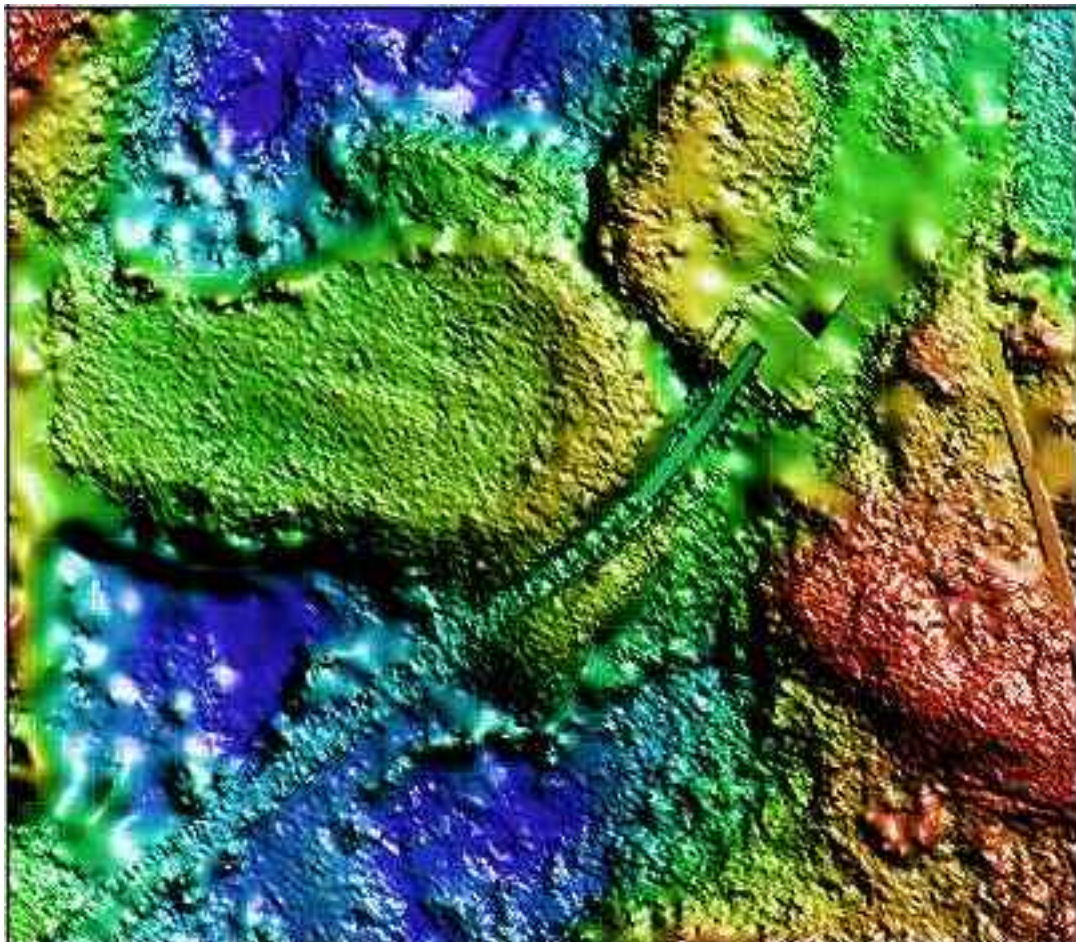




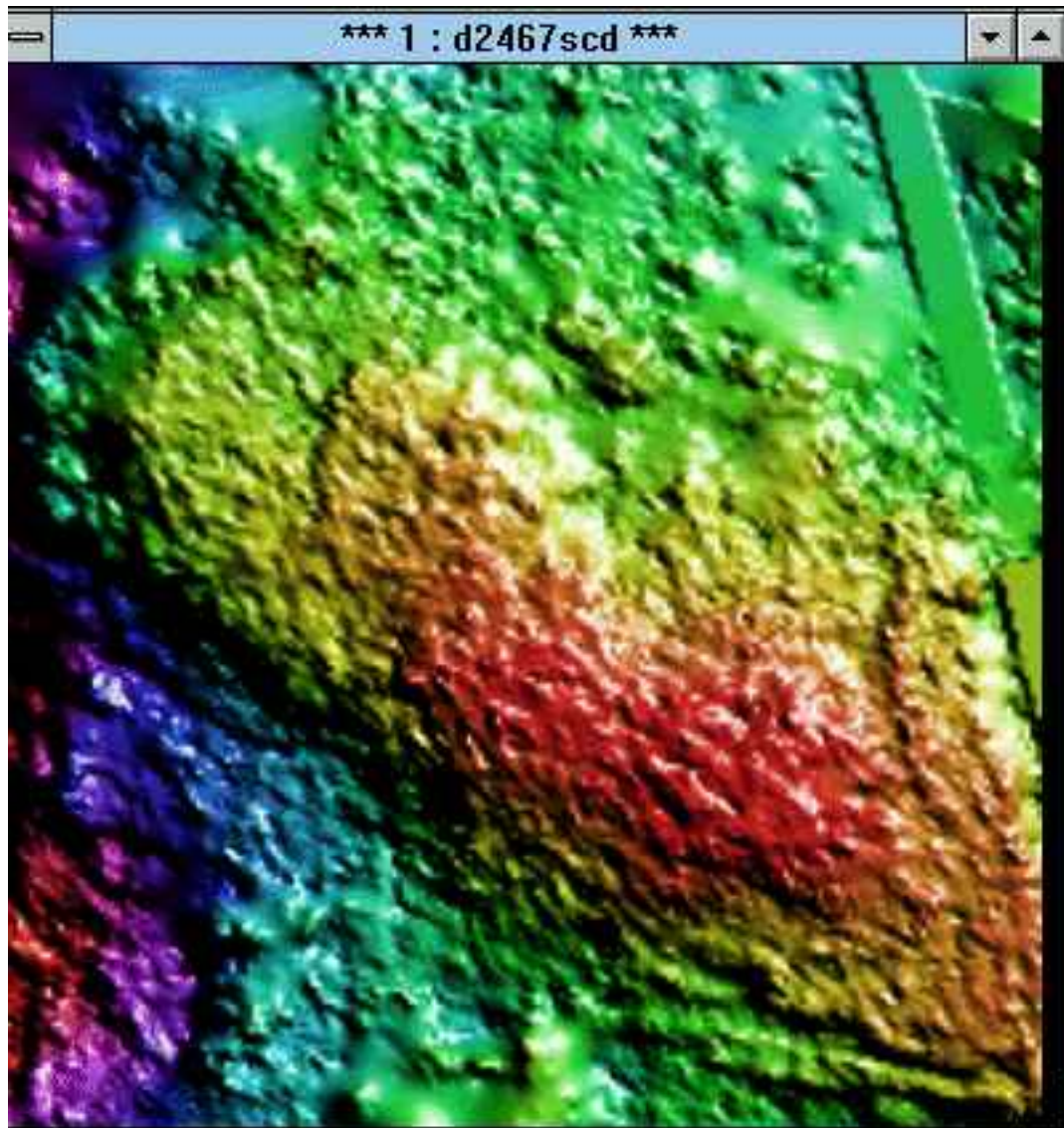




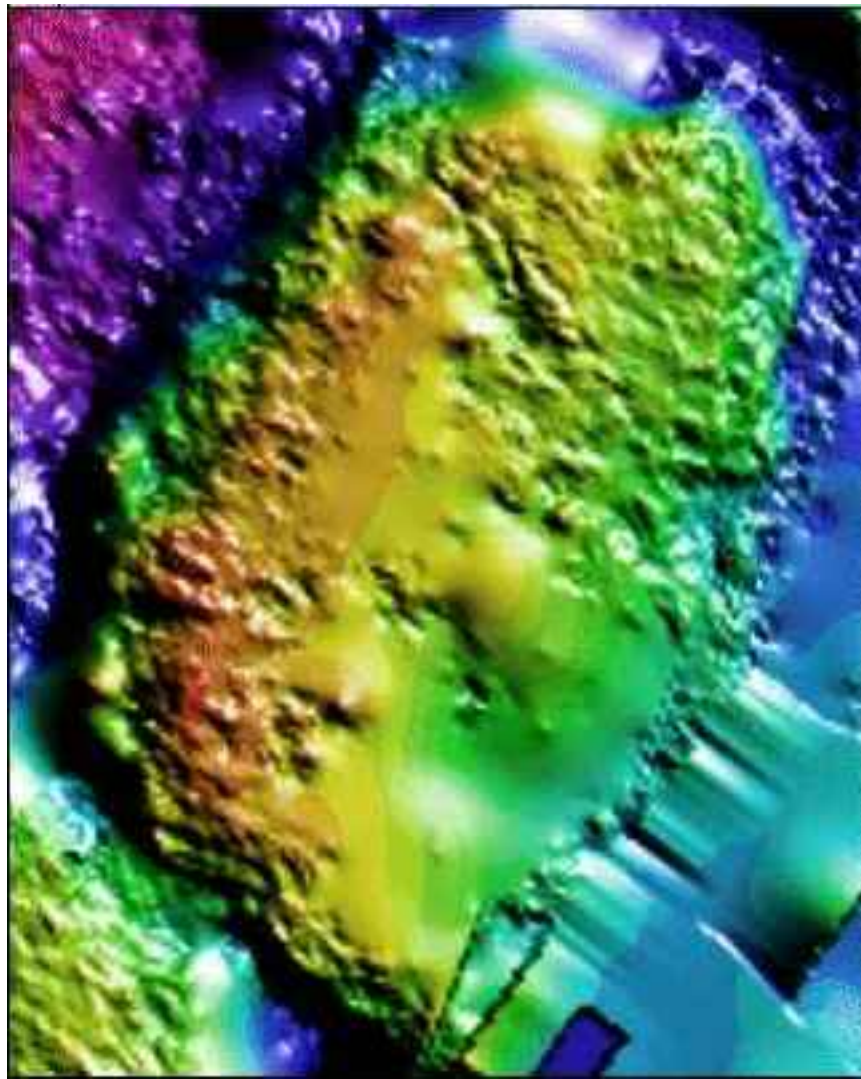


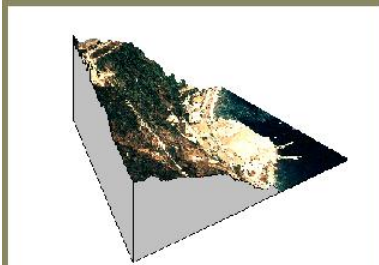




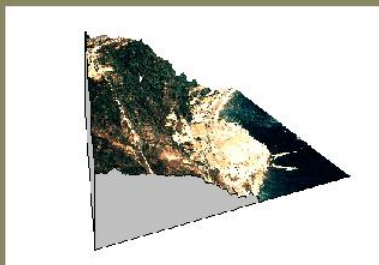




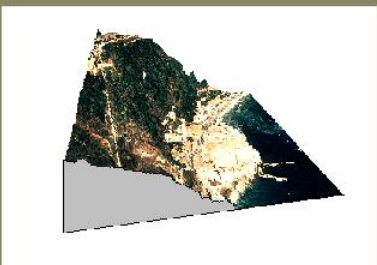




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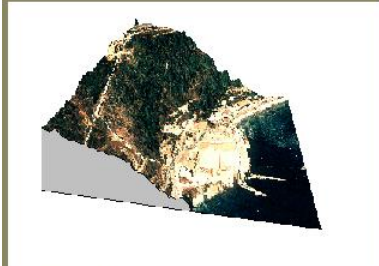
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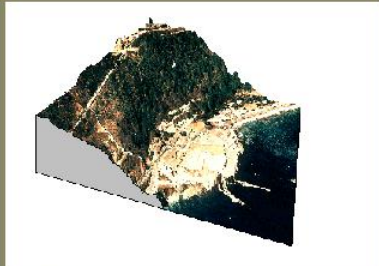
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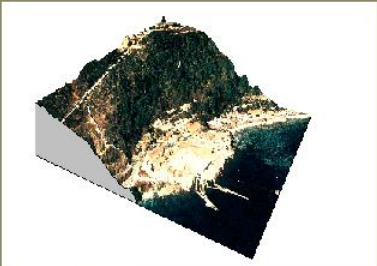
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2368kp10.bmp



2368kp11.bmp



2368kp12.bmp



2368kp13.bmp



2368kp14.bmp



2368kp15.bmp



2368kp16.bmp



2368kp17.bmp



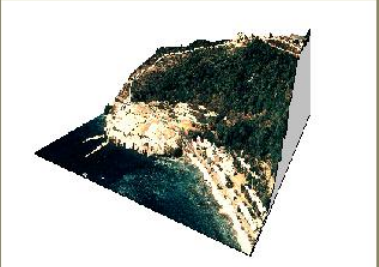
2368kp18.bmp



2368kp19.bmp



2368kp20.bmp



2368kp21.bmp

