CHAPTER 2 GENERAL DESCRIPTION OF STUDY AREA

2.1 Geomorphology

Geomorphology of the study area was interpreted by using LANDSAT/TM images and monochromic aerial photographs. The results are shown in Table 2.1-1 and Fig. 2.1-1.

Table 2.1-1 Geomorphologic Interpretation Chart

Unit Name	General Altitude	Geomorphology	Other Ground Surface Characteristics
Hh	High	Hill	Even and inclined with smooth surface
Hm	Moderate	Hill	Even and very smooth surface
Hl	Low	Hill	Rough texture
Sd	-	Sand Dune	Yellow coloured linear texture with N-S direction
Bd	Low	Bed Rock	Colours and geomorphology depending upon their geology
Vg	-	(Vegetation)	Generally sparse

In general, topography of the study area is flat, of which gradient is 2/1000 in average. Elevation of the study area decreases toward southeast from 1,500m to 950m.

The characteristics of geomorphology are closely related to the geology of the study area. Most of the areas where Kalahari calcretes crop out show significantly flat. However, the western and southern parts of the study area form cliffs or steep slopes, where the sandstones of the Nossob and the Auob Members, basalts of the Kalkrand Basalt and dolerite sills are distributed widely. These features provide three categories of hilly topography that are called high, moderate and low hills in relation to their altitudes, textures and so on.

The sand dunes developed in the northern and central part of the study area indicate typically linear shapes in all sizes, affected by seasonal winds in NW-SE direction. These dunes and other sand covers seal bedrocks under beneath. Vegetations are mainly composed of natural colonies, but cultivated areas represented by the Hardap irrigation scheme are apparently extracted from the images.

Drainage is divided into two groups. One is an external drainage such as surface streams and the other is an internal drainage, which is called as "Pans" in this district developed from sinkholes in the distribution area of the Kalahari Member. They show almost circular or ellipse shapes with numerous sizes in their diameters.

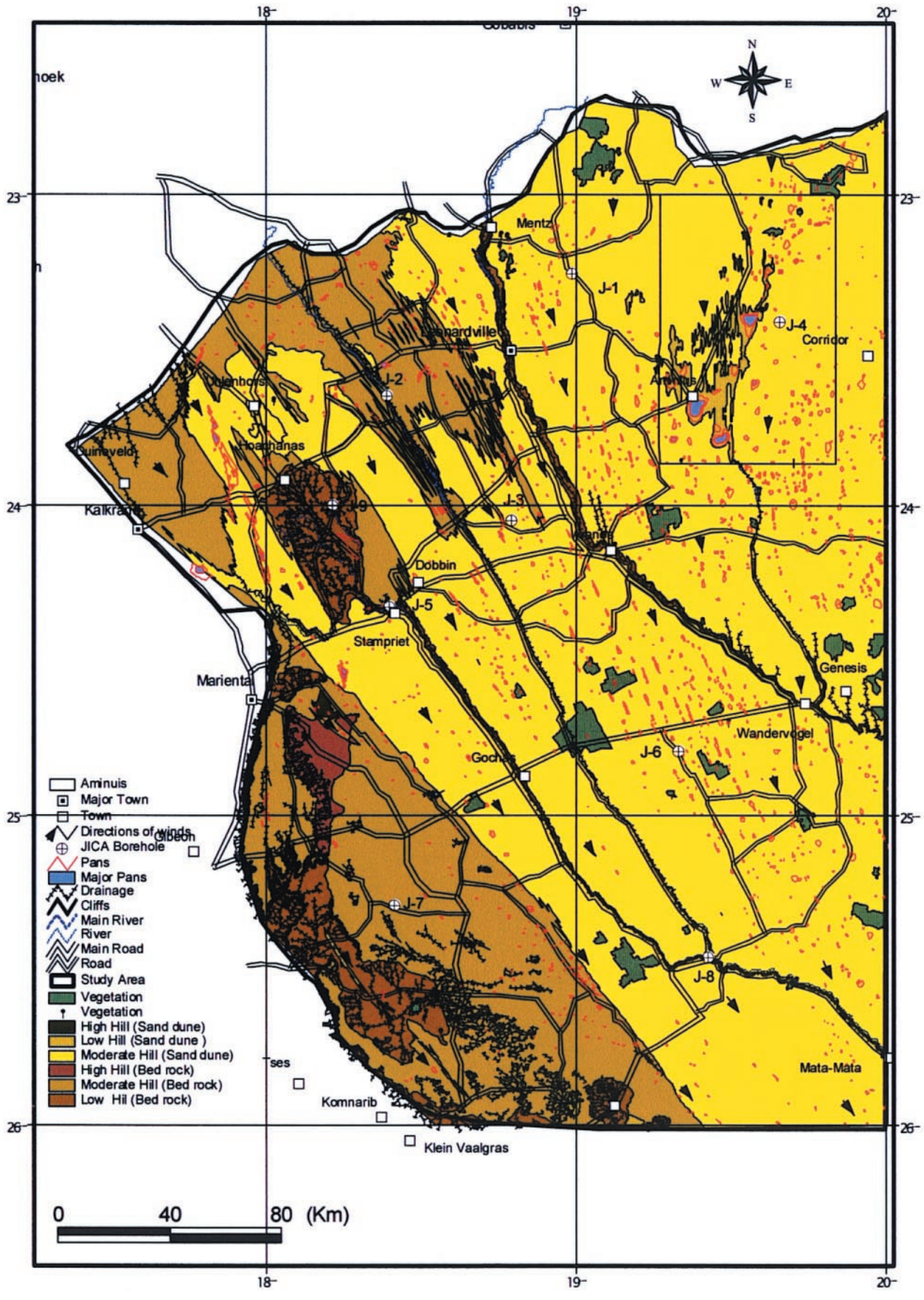

Fig. 2.1-1 Geomorphology of the Study Area

2.2 Geology

2.2.1 General Geology

Geology of the study area owes to previous contributions by Heath (1960), Martin (1963), Kingsley (1985), CDM Mineral Surveys (CDM, 1982, 1983; McDaid, 1982, 1983), Gold Fields Prospecting (Castelyn, 1983), Agip Carbone (1982, 1983) and Geology of Botswana (J.N.Carney et al.,1994).

Although different classifications were presented in the previous studies, geology of the study area is summarized in Table 4.1-1 following "Mineral Resources of Namibia"(MSN, 1992).

The Damara Sequence, the Nama Group and the Dwyka Group are regarded as the basement rocks of the study area because they serve as an impermeable layer from a hydrogeological point of view. The Damara Sequence and the Nama Group were formed through the Pan–African Orogeny or Movement. The Dwyka Group consists of glacial sediments that were deposited in the late Carboniferous to the early Permian Period.

The Nossob and the Auob members as the major aquifers in the study area are included in the Prince Albert Formation that consists mainly of sediments that were deposited in the early Permian Period in a basin in which water depth fluctuated through time.

Faults and dolerite dykes or sills occur in the Prince Albert Formation. The Kalkrand Basalts were formed widely in the northwestern part of the study area, namely the north of Mariental. The Kalahari Beds, of which age is from the late Cretaceous to the Recent, were deposited on an erosional landscape known as the "African Surface" into which a deep "Pre-Kalahari Valley" was eroded.

A geological map, geological cross sections of the study area and location map of the sections are shown in Fig. 2.2-1, Fig. 2.2-2 to Fig. 2.2-5 and Fig.2.2-6 respectively.

Table 2.2-1 Stratigraphy in the Study Area

Era	Period	Formation	Lithology	Thickness	Note
Cenozoic	Quaternary 2Ma / Tertiary 65Ma	Kalahari Beds	Sand, gravel, calcrete,calcrete-cemented conglomerate	0 (W)–290 (E)	"Kalahari Beds" is an informal lithostratigraphical term. They rest on an erosional landscape known as the "African surface" (Pre-Kalahari Valley).
Mesozoic	Cretaceous 143Ma	Karoo Sequence	–	–	–
	Jurassic	Karoo Sequence	Dolerite	100?	Many of the faults in the Karoo Sequence have been intruded by dolerite dykes.
		Karoo Sequence	Basalt; thin interbeded pan sandstone and sandy limestone with abundant gypsum casts. Equivalent age intrusive dolerite dykes and sills	0–370	Rifting of the Gondwana supercontinent (180 Ma in eastern South Africa; 128 Ma in Namibia)
	212Ma Triassic 247Ma	Karoo Sequence	–	–	–
Paleozoic	Permian	Ecca Group, Prince Albert Formation, Rietmond member	Multicolored sandstone (mainly brown), shale, yellow shale, coal, black shale	50–100	Lower Ecca subgroup was deposited in lakes and deltas in the post-glacial environment following the retreat of the Dwyka glaciers. The middle and upper subgroups were mostly formed in rivers and deltas under subarctic to cool temperature climatic conditions and include the coal-bearing formations. Regional unconformity exists between Dwyka Group and Nossob member.
		Ecca Group, Prince Albert Formation, Auob member	Upper sandstone, upper coal, middle sandstone, lower or Impala coal, lower sandstone	27–153	
		Ecca Group, Prince Albert Formation, Mukorob member	Upper interbedded white siltstone and grey shale. Lower dark grey to black shale	57–102	
		Ecca Group, Prince Albert Formation, Nossob member	Two coarsening upward sandstone units	6–36	
	289Ma Carboniferous	Dwyka Group	Complex succession of lithofacies, commencing with a basal tillite followed by glaciomarine mudstones with dropstones and minor, local glaciofluvial sandstone		The western margin of the glacial "Kalahari Basin" was inundated by the arm of a shallow sea.
	367Ma Devonian 415Ma Silurian 446Ma Ordovician 500Ma	Karoo Sequence	–	–	–
	Cambrian	Nama Group	Upper Nama Group: Thick alternating units of red, distal molasse sandstone and shale. 545 – 530 Ma.	–	The sediments were folded during later Pan-African movement until 420Ma. Nama G. have been affected by northeast-trending faults that define a half-graven structure. ACP21 reached to fine-grained Nama quartzite in Aranos.
	575Ma	Nama Group	Lower Nama Group: Basal sandstone, black shelf limestone, upper grey shales with sheet sandstones. 650 – 545 Ma		
Proterozoic	Pre-Cambrian	Damara Sequence	Complex orogenic succession of sedimentary and volcanic rocks; deformed, metamorphosed and intruded by granite during Pan-African Orogeny. 900 – 505 Ma	–	"Damara Sequence" The various units were accumulated between about 900Ma and 530Ma and were folded and faulted during the Pan-African deformation.

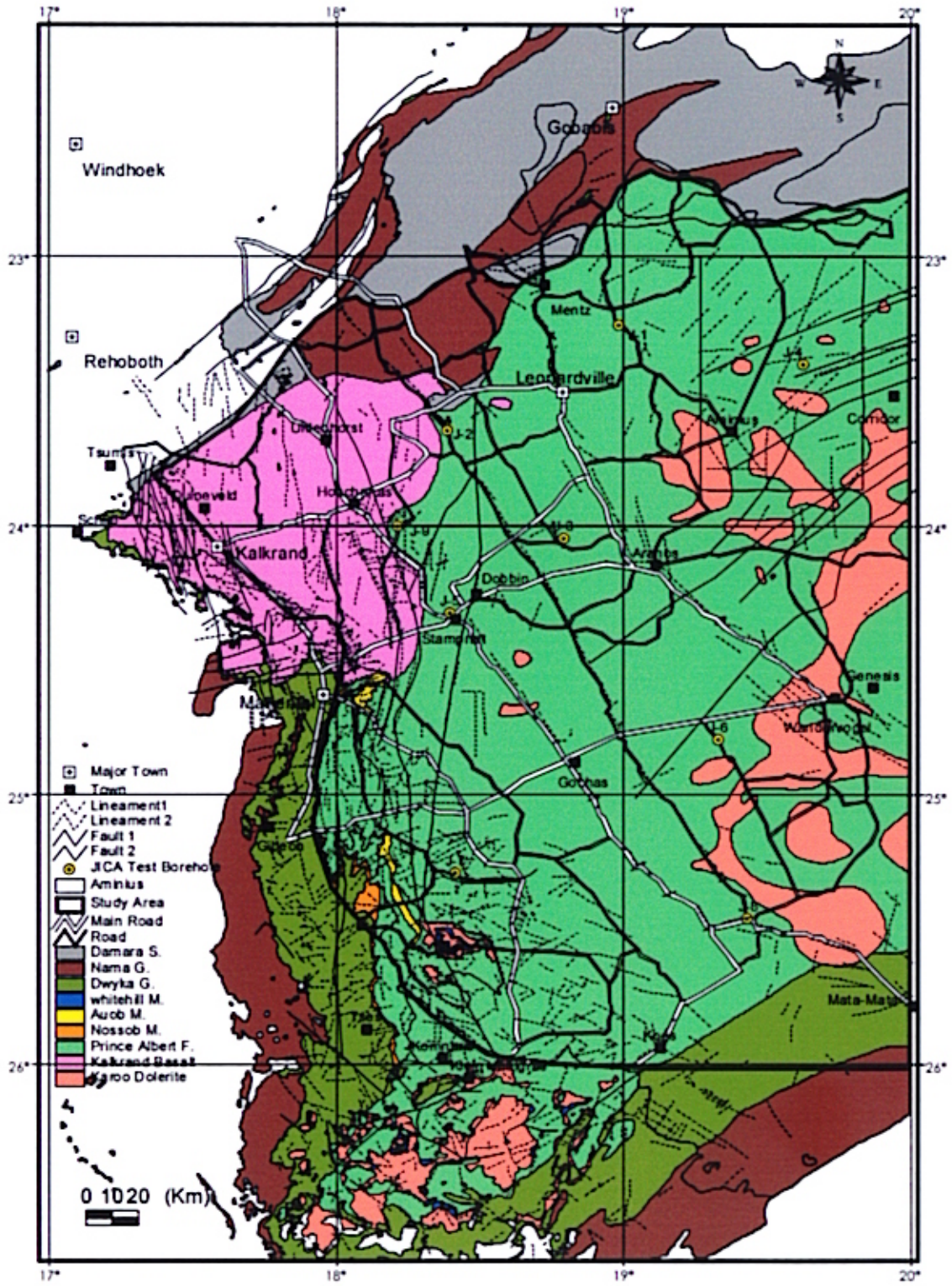

Fig. 2.2-1 Geological Map of the Study Area