Identification and Mapping of Calcrete Deposits in Inhambane Province and Preparation of a Calcrete Classification System and Specifications for the Use of Calcrete in Road Construction in Mozambique
AFCAP/MOZ/091

FINAL REPORT

Report No. RPN 2551

TRL Limited, UK, in Association with InfraAfrica (Pty) Ltd, Botswana and Hearn Geoserve Ltd

March 2013

This project was funded by the Africa Community Access Programme (AFCAP) which promotes safe and sustainable access to markets, healthcare, education, employment and social and political networks for rural communities in Africa.

Launched in June 2008 and managed by Crown Agents, the five year-long, UK government (DFID) funded project, supports research and knowledge sharing between participating countries to enhance the uptake of low cost, proven solutions for rural access that maximise the use of local resources.

The programme is currently active in Ethiopia, Kenya, Ghana, Malawi, Mozambique, Tanzania, Zambia, South Africa, Democratic Republic of Congo and South Sudan and is developing relationships with a number of other countries and regional organisations across Africa.

This material has been funded by UKaid from the Department for International Development, however the views expressed do not necessarily reflect the department's or the managing agent's official policies.

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Contents

1 Background

Road-building materials meeting conventional specifications are scarce along much of the coastal and inland areas of Mozambique and, in particular, in Inhambane Province. The non-availability of good natural gravels for the construction of wearing courses has resulted in high maintenance costs for unpaved roads and expensive options such as chemical and bituminous stabilisation of sand for the construction of sealed roads in the province. The main locally available gravel material is calcrete, which in the past was considered as marginal because it frequently does not meet traditional specifications for road construction. However, calcrete has been used successfully elsewhere in the region in similar situations where good roadbuilding materials are scarce. If calcrete deposits in the province can be relatively easily located and appropriate specifications derived for their use, then this will lead to more appropriate and extensive use of this material for road construction.

TRL, in collaboration with the Aministracao Nacionale de Estrades (ANE) and assisted by Hearn Geoserve Ltd and Infra Africa was commissioned to undertake a study under the DFID/ANE-funded Africa Community Access Programme (AFCAP). The main purposes of the project were to provide guidance to ANE and the Inhambane provincial authorities on locating calcrete deposits and to assess their properties in relation to existing technical specifications for their use in road construction.

2 Purpose of this report

This report contains a summary of the objectives, presentations, discussions and outputs from the workshop and associated field visit.

The workshop programme is given in Appendix A.

3 Workshop objectives and activities

The workshop described in this report was held to present the objectives, methodology and outcomes of the project to practitioners in the road sector and to provide participants with an opportunity to contribute to discussions on the project outputs and recommendations for future work.

ANE staff from the four provinces (Inhambane, Sofala, Maputo, Zambezia and Gaza), where significant deposits of calcrete occur attended the workshop, together with representatives from the ANE and LEM materials testing laboratories.

Presentations were made by the various members involved in the project and included a presentation on the current use of calcretes in research projects in Mozambique, with opportunities provided for questions and discussion.

The workshop activities also included a field visit to selected locations where calcretes had been located.

An early draft of the project report was also distributed to the workshop participants.

4 Topics covered

A brief summary of the content of the presentations are give in this section of the report. The workshop presentations are given in Appendix B and covered each of the main project areas as well as providing an oversight of existing research projects in the road sector using calcareous materials.

The presentations covered the following main theme areas of the project:

- Project objectives
- Remote sensing using aerial photography and satellite imagery
- Field prospecting
- Mapping of potential deposits
- Trial pitting and material sampling
- GIS and database
- Materials testing and specifications
- Current road research projects in Mozambique using calcrete.

4.1 Project objectives

The project objectives can be summarised as follows:

- Location (prospecting for) road-building material (calcretes) in Mozambique (Inhambane province)
- Testing and classification
- Specifications for the use of calcretes in roadbuilding

Full details of the objectives and project deliverables are given in the Final Project Report.

4.2 Project activities

The main activities undertaken included:

- Review of existing published information

- Examination of aerial photographs and geological, topographical and soil maps of the province
- Review of available information use satellite imaging (LANDSAT, SPOT, ASTER)
- Survey of prospective sites using a calcrete probe and augering
- Test pitting in prioritised areas
- Sampling of materials
- Testing of samples
- Comparison of results with existing specifications
- Revised maps showing possible sources of calcrete
- Development of GIS and database
- Reporting

The presentation on the objectives of the project also included an introduction to the various types of calcretes and a brief reference to their mode of formation and occurrence in the region.

4.3 Remote sensing, field prospecting, GIS and database

These activities together comprised a major component of the project and were covered by two presentations in the workshop.

The first of these presentations covered background information on the formation of calcrete and experience from previous remote sensing studies undertaken in Sothern Africa, particularly in Botswana and the typical field investigations used to locate calcareous materials. Photographs of the typical types of calcrete were given and of the vegetation associated with these deposits of calcareous. Not all calcareous material found in Inhambane is calcrete.

In the second presentation, details were given of the methodology used to detect deposits of calcrete in Inhambane province. This began with a survey of existing calcrete borrow pits and relating these to the indicators derived from aerial photographs and satellite imagery. The main difference from the Botswana model is that in Inhambane, deposits of calcrete are not found in 'pan' areas, although they are often primarily associated with general low-lying areas, which can be identified by examination of stereo pairs of aerial photographs and satellite imagery. Investigations with a calcrete probe and an auger were used to detect the presence of calcrete.

Also presented was the outcome of the various phases of remote sensing and field surveys, which enabled a geomorphological map to be prepared which also shows probable sources of calcrete together with the identification of priority sites for further field investigations. The use of ASTER data was a critical factor in identifying future areas to be investigated.

The GIS and database components of the project were also included in this presentation. The GIS links the layers of the various location and other data for the deposits investigated and can be linked to additional sources of information. The live link ensures that the latest data is available. Potential, active and exhausted sites are included together with discounted sites that can be excluded from future prospecting on the basis that no calcrete was located. Provision for the location of individual trial pits within a potential deposit is also included. Various material tests are included in the database with a provision for additional tests to be added.

4.4 Trial test pitting and sampling

Two presentations covered the methodology used in testing pitting and sampling, which was organised and supervised by ANE. Test pitting was done by labour which is a time-consuming exercise with limitations on the depth of material that can be excavated safely. Due to time constraints, it was possible to excavate just one pit at each of the priority areas identified from the remote sensing activities. Samples of material were taken according to a previously agreed methodology. The approximate lateral extent of the deposit was investigated up to an area of 200m by 200m and to a depth of approximately 1.8m using the calcrete probe. Samples were bagged and transported to the ANE and LEM laboratories for testing.

Photographs of the types of vegetation that occur on calcareous soils were presented and samples of the plants circulated amongst the workshop participants.

4.5 Materials testing and specifications

This presentation covered the results of the material testing programme and existing specifications for the use of calcrete in road construction. Three ‘identical’ samples of material were prepared from each trial pit and one sample each dispatched to the LEM laboratory at Maputo, and the ANE laboratories at Maxixe and Maputo. The quality of materials in calcrete borrow pits varies significantly both laterally and with depth. Therefore, the results of tests from just one pit are unreliable and additional pitting, sampling and testing is required for these locations. There were additional problems related to the calibration of testing equipment and the different test methods being used that further complicated interpretation of the test results. The results of the limited testing undertaken were presented and discussed in relation to existing specifications together with outline recommendations for their possible use in Mozambique. An example of a road construction project in Botswana was also presented in which calcareous materials that did not meet conventional specifications had been used for the construction of 300kms of sealed road crossing the Kalahari to Namibia.

4.6 Road research projects using calcrete

Examples of ongoing research projects involving the use of calcareous materials in Mozambique were presented. The presentation reiterated the lack of good quality materials in Inhambane that meet conventional specifications materials. The research projects include the blending of sand with calcrete, using calcrete for armouring of road base, the use of calcrete as a surfacing aggregate in Otta seals and highlighted the need for long-term monitoring. D

5 Issues and questions raised in discussions

The outcome of the discussions which ensued during and subsequent to the presentations and responses to questions raised are summarised below:

- The difference between the different forms of calcium carbonate-bearing materials, particularly limestone and calcrete was clearly an issue. In the context of calcrete formation, tertiary limestone was formed under the sea millions of year ago and provides a source of the calcium carbonate which, in solution, indurates and precipitates in the host soil to form calcrete.

- The limestone and harder forms of calcrete were not tested in this project but these materials have been used as roadbuilding material elsewhere and can provide a source.
- Testing with dilute hydrochloric acid is used to detect calcium carbonate with which it reacts (with obvious effervescence) to produce carbon dioxide. Commercially available swimming pool acid from a local supermarket was used on site.
- On the subject of vegetation that occurs in calcrete-bearing soils, the thorny plants found can also amongst other vegetation but they are more abundant in calcareous soils.
- The measurable thickness of the deposits found in this preliminary prospecting exercise was limited to approximately 1.8 metres using the calcrete probe and augering and to 2 metres in the trial pitting. This included the depth of overburden. The average depth of the calcrete investigated was approximately one metre but the full depth (i.e. lower limit) of the calcrete seams was not determined. The approximate minimum area of the deposit was determined up to a maximum area of 200m x 200m using the probe. Subsequent trial pitting, sampling and testing will be required in the usual prescribed way to determine the full extent, depth and quality of the materials present.
- The hardpan calcrete is usually found as hard layer in the upper layers of calcrete deposits which, in Inhambane, are often associated with grey sand but an observation was made from a presentation that a hard deposit was found at depth in an area of red sand. This could be a limestone deposit or an older deposit of calcrete.
- The GIS was still being developed at the time of the workshop but it was explained that the development of the associated database will continue with the facility for additional data being added by ANE.
- The outcome of materials testing component of the project was clearly of some concern. Within the time and resource constraints of the project, it was possible to sample from only one trial pit in each of the areas which had been identified from the remote sensing and surface surveys for priority investigation.
- Material in calcrete borrow pits tend to vary in quality both in extent and with depth due the mode of formation and a single sample can provide only a limited indication of the material available. However, the results did raise questions about sampling sizes for testing, the test methods being used and the calibration of testing equipment.
- Specifications developed for the use of calcretes in the region were presented. It is clear that the above issues with respect to testing will have important implications in deciding which specifications should be used pending development of specifications for calcretes in Mozambique. These are important issues that need to be resolved.
- The final presentation was on ongoing research by ANE in Mozambique using calcareous material. Of particular interest were the use of sand/calcretes blended material and the use of calcretes as aggregate in Otta seals.

6 Conclusions, Recommendations and Way forward

The results of the prospecting together with conclusions and recommendations are included in the Final Project Report but are also presented here as information for the workshop participants who may be involved in further prospecting activities in Inhambane or other provinces in Mozambique.

6.1 Conclusions

- Comparing ground and environmental conditions found at existing calcrete borrow areas in Inhambane Province from stereo aerial photography and satellite imagery provides an indication of similar conditions elsewhere.
- The landform indicators used in Botswana were not generally applicable in Inhambane Province.
- Vegetation types associated with calcrete in other parts of Southern Africa also indicated a presence of calcrete in Inhambane Province.
- The calcrete probe and a hand auger were useful tools in confirming (or otherwise) the presence of calcrete at the predicted locations.
- Examination of satellite imagery using the known calcrete locations as control can be used to identify common visual and spectral signatures to extrapolate the same conditions to other areas for prospecting purposes.
- The ASTER data was helpful in mapping low-lying areas with which calcrete deposits are associated and can be extrapolated to other areas for prospecting purposes.
- A preliminary Geomorphological and Calcareous Materials Map for Inhambane Province at 1:250,000 scale was produced.
- A list of 48 calcareous locations (additional to the existing calcrete borrow areas) where either remote sensing, surface probing investigations or outcrop gave rise to the identification of calcareous materials.
- 16 sites were considered likely to be *in situ* Tertiary limestone, Tertiary calcareous sandstone or Quaternary coralline materials (i.e. definitely not calcrete)
- 8 sites were considered likely to be calcrete based on the probe results, but were not investigated with trial pits
- 5 sites were considered to be lacustrine limestone based on probe results and the published outcrop pattern, but were not investigated with trial pits
- 6 sites were considered likely to be either calcrete or lacustrine limestone, based on surface evidence, i.e. ‘outcrop’, but were not investigated by trial pits;

  Of the 13 sites investigated by trial pits:

  a) 10 yielded calcrete
  b) 1 yielded what is considered to be Tertiary limestone, and
  c) 2 yielded sand only.

6.2 Recommendations and way forward

It is recommended that the following actions are taken in relation to the outcome of this study:

- Investigate further the proven calcrete deposits (i.e. the 8 out of the 10 positive trial pitting investigations undertaken during this study). This will require the use of a back hoe to excavate a greater number of pits at each location to a greater depth in order to determine the quality and variability of the material in each case.
- Collect samples at each of these additional trial pits and carry out the tests previously scheduled.
- Take samples from some of the borrow areas in the mapped Lacustrine Limestone between Mabote and Tome and carry out the same tests on these for comparison.
- Undertake a trial pit investigate of the remaining 8 suspected calcrete locations and collect samples for testing.
- Carry out a probing investigation of the 36 additional potential calcrete locations identified from the Google Earth imagery and listed in the Final project Report.
- Use the ASTER imagery to assist in future campaigns for calcrete prospecting.
- Extend the methodology applied in this study to other Provinces where there is a potential presence of calcrete. According to the rainfall map of Mozambique this would include Gaza, Maputo and Tete Provinces.

7 Field visit

An important component of the workshop activities was a field visit that enabled workshop participants to relate the remote sensing, prosp
ecting and sampling techniques presented at the workshop to the field conditions where calcrete had been located.

Activities in the field included demonstrations and hands-on use of the calcrete probe and augering techniques as well as an opportunity to observe typical plants that occur in areas with calcareous soils.

It was also an opportunity to observe and handle samples of typical calcareous materials.

APPENDIX A

Workshop Programme

CALCRETE PROJECT WORKSHOP

Outline Programme

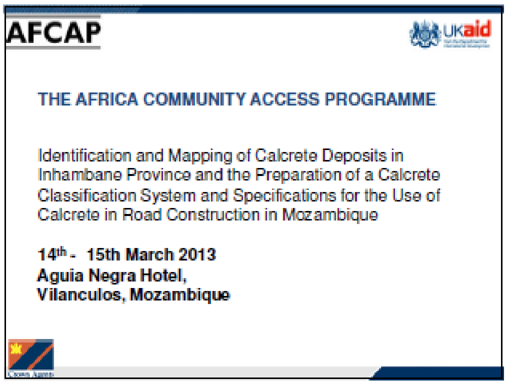
Thursday/Friday 14/15th March 2013
Vilanculos, Mozambique

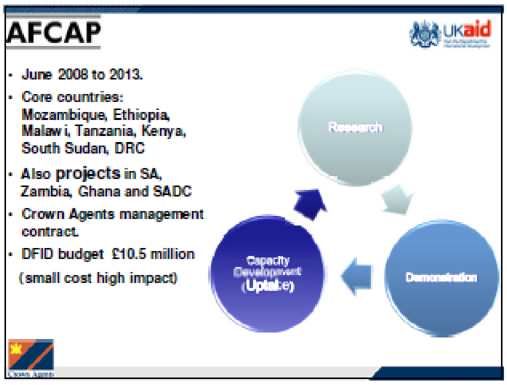
Time	Subject	Presenter
08.00 - 08.30	Arrivals/Registration	
08.45	Opening	Albino Novela Provincial Director of Public Works and Housing
09.00	AFCAP	Nkululeko Leta
09.15	Background to project	Tony Greening
09.30	Introduction to remote sensing techniques	Gareth Hearn
10.00	Coffee / Tea break	
10.45	Remote sensing for calcretes in Inhambane province	Gareth Hearn
11.15	On-site surveying	Joana Guiuele Francisco Menheche
11.45	Test results and specifications	Tony Greening
12.15	Discussion	
12.30	Lunch	
14.00	Research on use of calcrete in Inhambane	Kenneth Mukura
15.00	Coffee / Tea	
15.30	Summary	Tony Greening Gareth Hearn
16.00	Closure	Eng Fernando Dabo (ANE Delegado – Inhambane Province)
Friday 14 March 08.00 – 16.00	Site visit	Workshop Participants

APPENDIX B

Workshop Presentations

The Africa Community Access Programme
by Nkululeko Leta


AFCAP
UKaid
THE AFRICA COMMUNITY ACCESS PROGRAMME
Identification and Mapping of Calcrete Deposits in Inhambane Province and the Preparation of a Calcrete Classification System and Specifications for the Use of Calcrete in Road Construction in Mozambique
14th - 15th March 2013
Aguia Negra Hotel,
Vilanculos, Mozambique


AFCAP
UKaid
June 2008 to 2013.
Core countries: Mozambique, Ethiopia, Malawi, Tanzania, Kenya, South Sudan, DRC
Also projects in SA, Zambia, Ghana and SADC
Crown Agents management contract.
DFID budget £10.5 million
(small cost high impact)
Research
Demonstration
Capacity Development (Uptake)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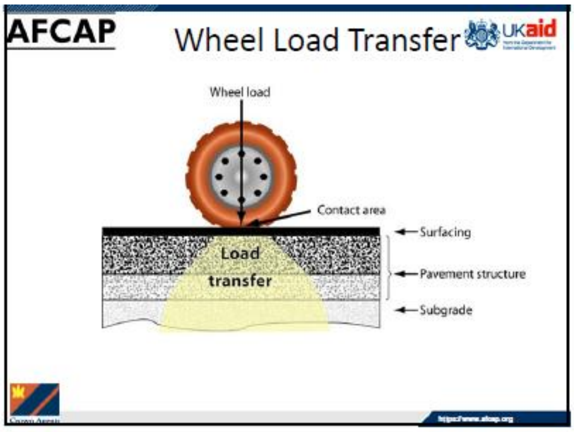
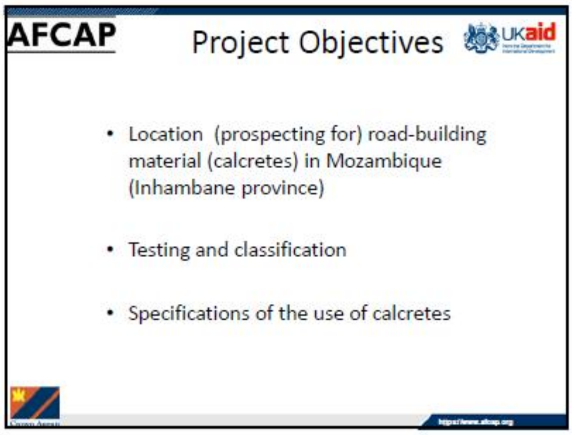
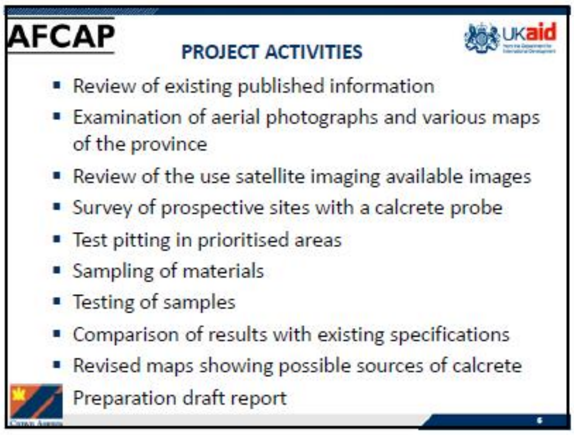
THE AFRICA COMMUNITY ACCESS PROGRAMME

Calcrete as a roadbuilding material
by Tony Greening


AFCAP
UKaid


AFCAP
Wheel Load Transfer
UKaid
Wheel load
Contact area
Surfacing
Load transfer
Pavement structure
Subgrade


AFCAP
Project Objectives
UKaid
• Location (prospecting for) road-building material (calcretes) in Mozambique (Inhambane province)
• Testing and classification
• Specifications of the use of calcretes


AFCAP
PROJECT ACTIVITIES
UKaid
▪ Review of existing published information
▪ Examination of aerial photographs and various maps of the province
▪ Review of the use satellite imaging available images
▪ Survey of prospective sites with a calcrete probe
▪ Test pitting in prioritised areas
▪ Sampling of materials
▪ Testing of samples
▪ Comparison of results with existing specifications
▪ Revised maps showing possible sources of calcrete
Preparation draft report

AFCAP

IMPORTANCE OF MATERIALS IN ROAD CONSTRUCTION

- Materials typically make up to 70% of total cost of road
- 90% of problems occurring on low-volume roads are materials related
- Large benefits from knowledge about use of local materials

AFCAP

ROAD BUILDING MATERIALS

- Road building materials mostly derived from weathering and pedogenesis
- Each group has a characteristic range of properties and potential problems which should be taken into account by test methods and specs
- Conventional specs often unnecessarily restrictive and can result in costly failures as well as over-conservative , uneconomic designs
- Specs tied directly to test methods used in carrying out research work – dangerous to mix.

AFCAP

FORMATION OF CALCRETE

- Calcareous materials are formed by pedogenisis.
- In times of high rainfall calcium (and magnesium) carbonates dissolve and the resulting solution indurates existing soils.
- Carbonates are precipitated out of solution and replace the host material.
- Repeated action over long periods lead to deposits of calcrete
- Other pedogenic materials are formed in similar process - silcrete (with silica) and laterite (mainly with oxides of iron)
- The materials harden in time to the various forms of calcrete: calcified sand (rarely other host material), powder, nodular, boulder/hardpan calcrete

AFCAP

Types of calcrete

- Boulder
- Hardpan
- Nodular
- Powder
- Calcified (sand)

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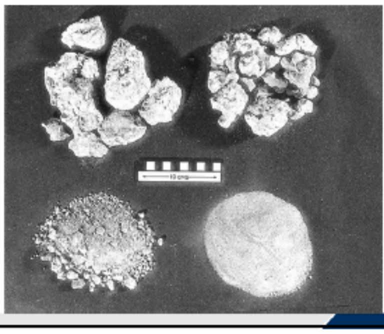
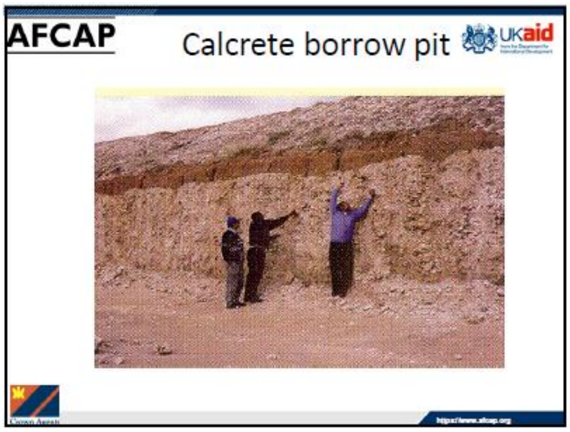
EXAMPLES OF TYPICAL TYPES OF CALCRETE USED IN ROAD

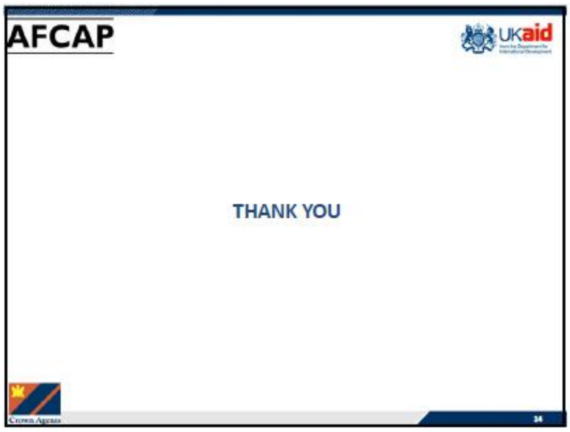


AFCAP

USE OF CALCRETES IN ROAD CONSTRUCTION

BOULDER/HARDPAN (CRUSHED)	Surfacing aggregate
NODULAR	gravel wearing course natural (uncrushed) as base course in sealed roads
POWDER	gravel wearing course base course (LVSR's) sub-base
CALCIFIED (sand)	sub-base (LVSR's)


AFCAP
Calcrete borrow pit
UKaid


AFCAP
UKaid
THANK YOU

Introduction to calcrete sources: Inhambane in a South African context

By Gareth Hearn

ANE Administração Nacional de Estradas

Introduction to Calcrete Sources: Inhambane in a South African Context

Presented by Dr Gareth Hearn

14th March 2013

Crown Agents

TRL

UKaid

Contents of this Presentation

- Definitions
- Climate, Soils and Vegetation the Development of Calcretes
- Calcretes in Southern Africa and the N = 5 line
- Experience Mapping Calcretes in Southern Africa
- Existing Borrow Pits in Southern Inhambane Province
- Other Calcareous (and non-calcareous) Materials

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Definitions

- Pedocretes:
  - Materials that have formed in place, either at or below the surface as a result of weathering, cementation or replacement of existing soil particles by minerals precipitated from soil water or groundwater
- What used to be called
  - Surface limestone is now referred to as calcrete
  - Surface ironstone as ferricrete
  - Surface quartzite as silcrete

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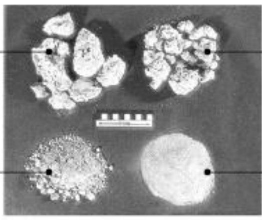
Different types of calcrete



Page • 4

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Climate and Calcrete Development

*The correlation between the distribution of calcretes and climate is marked. In Southern Africa well-developed calcretes … usable as construction materials generally only occur where the mean annual rainfall is less than about 550mm. The N = 5 line also affords a good correlation with this limit of calcrete occurrence**

Note, however, that climate change during the last 100,000 years will have resulted in the formation of calcretes in areas with a topography and climate that may well be quite anomalous to the present day

*F Netterberg

Page • 5

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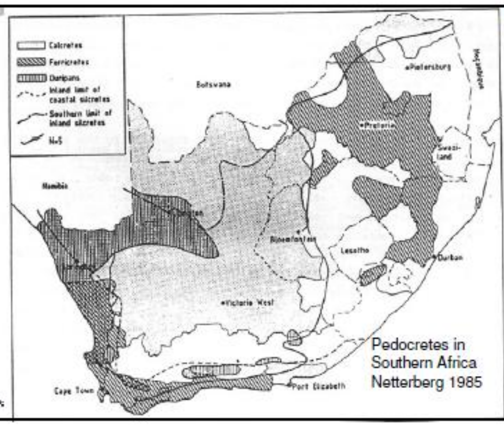

Pedocretes in Southern Africa Netterberg 1985

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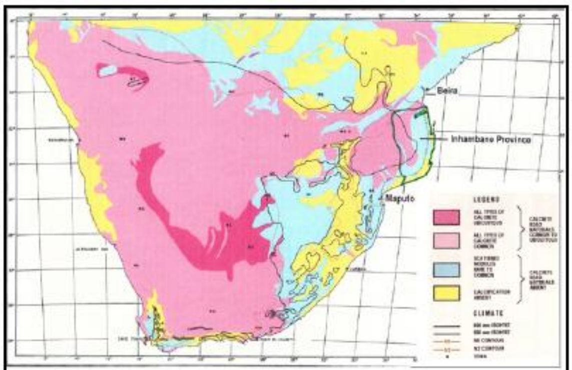


Calcrete Potential Based on 1:5,000,000 rainfall (Netterberg 1969)

Soils and Calcrete Development

- *Only when the soil profile is residual or the thickness of the transported cover is reasonably thin, does the solid geology determine whether or not calcrete will form. In such profiles, calcrete is likely over calcareous rocks, such as limestone, dolomite, calcareous shale and mudstone...Calcretes also sometimes mark faults...probably in many cases largely due to shallow water table conditions.*
- *A thickness of soil cover within certain limits appears necessary for significant calcrete formation. If the soil is too thin, little rainwater can be retained and calcrete formation is limited...If it is too thick and the water table is deep, the soil will absorb all the water and prevent...dissolution of the underlying rock*

Vegetation and Calcrete Development

Calcium/calcrete tolerant plants (Botswana MWTC)

Botanical Name	Common Name
Acacia fleckii	Blade thorn
Acacia mellifera	Hook thorn
Acacia nebrownii	Water acacia
Acacia reficiens	False umbrella thorn
Catophractes alexandri	Trumpet thorn
Combretum imberbe	Leadwood
Dichrostachys cinera	Sickle bush
Eriocephalus ericoides	Snow bush
Grewia bicolour	False brandy bush
Grewia flava	Brandy bush
Grewia flavescens	Donkeyberry
Maytenus senegalensis	Confetti tree
Pechuel-loeschea leubnitziae	Bitter bush
Tanchonanthus camphorates	Camphor bush
Terminalia prunoides	

Page • 9

Black Thorn Buffalo Thorn Camel Thorn

Page • 10

Camphor Bush Trumpet Thorn Kapok Bush

Page • 11

Experience Mapping Calcretes Elsewhere in Southern Africa

Techniques

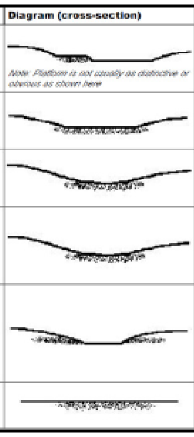
- Satellite and airborne remote sensing, using multi-spectral analysis and other sensors
- Characteristic landform mapping from aerial photograph interpretation and field mapping
- Field reconnaissance and detailed survey

Remote Sensing Options for Calcrete Prospecting

Selected studies

- Colour and black and white aerial photography proved highly useful in Botswana, for direct visual recognition of characteristic landforms
- SLAR – proved useful for calcrete mapping in Nigeria, especially useful where the vegetation is more dense
- Multi-spectral (including infra-red) analysis of satellite imagery: from Botswana false colour composites using Bands 4 (red), 5 (green) and 7 (blue) proved successful
- Landsat MS -unsuccessful in Namibia

Landform	Diagram (cross-section)
Pan with 'platform' Flat-floored pan with no or minimal vegetation. 'Platform' is a low bench situated on the edge of the pan but usually not extending all the way round. May be more than 500m across, or less	*Note: Platform is not usually as distinctive or obvious as shown here*
Pan without 'platform' Flat-floored pan with no development of a low bench around the edge. May be more than 500m across, or less. May be without vegetation, or contain grasses	
Depression Concave hollow in the sand surface, containing grasses. The grass communities are often arranged in concentric zones around the depression	
Inter-dune hollow Very long, straight concave channel in sand surface. One of many forming parallel linear rises with hollows between. Typified in the area south of Takatswaane. Calcretes are developed at intervals along the line of the hollow.	
Valley (old river channel) A dry river valley, filled in with sand. Takes the form of a broad, gentle elongated depression that extends for many kilometres, as seen between Khakea and Werda. In places, easily visible on the ground but in others, so wide and shallow as to be hardly detectable	
Grey sand No topographic relief, only grey sand contrasting with surrounding reddish or brown sands	

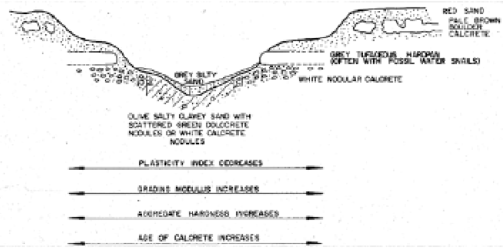


Typical 'Botswana' landform/calcrete relationships (Botswana MWTC)

Botswana: Pan morphology and calcrete occurrence

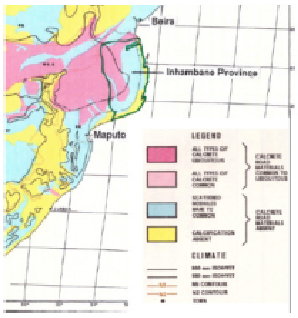
- Pans (approximately circular depressions of low relative relief) greater than or equal to 500m in diameter with a well-developed platform (or terrace) are almost certain to yield large quantities of reasonable quality calcrete in the platform and softer or plastic, lower quality material elsewhere in the pan;
- Pans greater than or equal to 500m in diameter without a well-developed platform are likely to yield low quality calcrete
- Pans less than 500m diameter with a platform may yield good quality calcrete in the platform, but quality and quantities may vary;
- Pans less than 500m without a platform may yield calcrete of unpredictable quality;
- Depressions will usually contain only poor quality calcrete. Grasses grow on the flat or concave floor of the depression to the exclusion of shrubs which grow on the surrounding plains;
- Grey sands occur without topographical expression and may contain poor quality calcrete in areas where no pans or depressions exist. They are usually covered by 1.5m of overburden.

Idealised section across calcrete-forming depression (from Netterberg 1969)



Typical Field Investigations

Reconnaissance survey	Detailed Survey
Purpose is to obtain an overview of the types and distribution of materials within the whole area of interest, i.e. to identify specific sites.	Purpose is to make a detailed record of the most appropriate sources of material for the project, i.e. to investigate specific sites identified in the reconnaissance survey.
Large distances are covered quickly to obtain an overview of potential sites and to cover as many of them as possible within the area of interest.	The sites are covered methodically, in much more detail. The coverage is planned to progress from one site to the next.
Usually no samples are taken, but a sampling plan is prepared.	Samples are taken as necessary, appropriate for the specification of the material in the context of the project.



Mozambique extract from Netterberg (1969)

Existing Calcrete Borrow Pits in Southern Inhambane Province

Existing Borrow Pit No	Road	Road No	Co-ordinates	Elevation from Topo Map	Material	Comment
EP 1	Chacane - Panda	R483	24°15'13.3"/ 34°51'51.9"	45-50m	Calcrete pan, nodular, boulder and conglomerate	Large area either side of road
EP 2	Chacane – Panda	R483	24°14'16.5"/ 34°52'07.1"	45-50m	Calcrete	In trial pits off RHS of road
EP 3	Panda Jangamo	?	24°07'08.2"/ 34°49'01.5"	70m	Calcrete, mostly powder calcrete, some clasts	
EP 4	Mocodoene -Mavaume	R902	23°33'48.5"/ 34°50'05.2"	100m	Calcrete, mostly nodular – difficult to say as there is no outcrop	Either side of road
EP 5	Funhalouro north	R904	23°03'01.3"/ 34°20'56.6"	130m	Calcrete pan overlying gravel sized nodules over powder calcrete, 1-1.5m total thickness	
EP 6	Track from EN1 to Magumbo village	None	23°39'29.4"/ 35°23'11.3"	Sea level +	Calcrete pan and nodules, soft material and very limited thickness	Hand dug excavations for local use

Page • 19


EP1 Chacane – Panda road, both sides of road

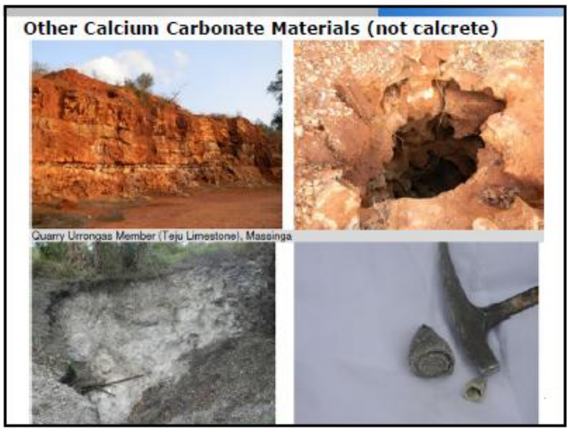
EP2 Chacane – Panda road


EP3 Panda – Jangamo road

EP4 Mocodoene-Mavaume, both sides of road


P5 Hardpan and nodular calcrete, Funhalouro

P6 Artisanal hand dug pits in calcrete, Magumbo village


Other Calcium Carbonate Materials (not calcrete)

Quarry Urrongas Member (Teju Limestone), Massinga


Borrow pit in Lacustrine Limestone on Mabote – Tome road

Quarry in coralline beds, Praia Tofu

Calcareous Materials in Inhambane

- Tertiary Limestone
- Tertiary Calcareous Sandstone
- Quaternary Coralline Materials
- Quaternary Lacustrine Limestone
- Quaternary Calcrete

Thank you for your Attention

'Who said its not calcrete!'

Calcrete prospecting in Inhambane province:
Remote sensing and field Mapping
By Gareth Hearn

ANE Administração Nacional de Estradas

Sourcing Calcrete in Inhambane Province: Remote Sensing and Field Mapping

Presented by Dr Gareth Hearn

14th March 2013

Crown Agents

UKaid

TRL

Contents of this Presentation

- Methodology
- Phase 1 Fieldwork – review of existing calcrete borrow pits
- Phase 1 Desk Study - preliminary Remote Sensing – Visual Interpretation
- Phase 2 Fieldwork – surface probing
- Phase 3 Fieldwork – trial pitting
- Phase 2 Desk Study – reassessment and analysis of remote sensing using the results of Phases 2 and 3 fieldwork
- Geomorphological and Calcareous Materials Map at 1:250,000 scale for Inhambane Province
- List of future prospects for calcrete probing and investigation

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Methodology

- Phase 1 Fieldwork: determine site characteristics of existing borrow pits using field reconnaissance
- Use remote sensing to identify:
  - a) where these characteristics can be found elsewhere
  - b) if the typical landform conditions indicative of calcrete in Botswana occur in Inhambane and investigate these for calcrete
- Phase 2 Fieldwork: based on the above use a calcrete probe and hand auger to test for calcrete from the remote sensing interpretations
- Phase 3 Fieldwork: carry out trial pitting in priority areas where probing had proven successful
- Use the results of the above to reassess the satellite imagery visually and digitally (using multi-spectral analysis) and based on a proven set of calcrete locations
- identify further sites for future prospecting by ANE

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Phase 1 Fieldwork: Existing Calcrete Borrow Areas

Borrow Pit No	Road	Field Notes Relevant to 'Characterisation' of Known Calcrete Deposits
1	Chacane - Panda	The topographic map indicates this whole area as 'lodo' meaning mud, clay, water-soaked earth. The area is flat except for occasional closed depressions and the soil is grey/black to dark brown slightly clayey silt. Higher ground to the south is approximately 50m above the low lying calcrete area. The change in elevation is however very gradual. The vegetation is sparse, being grassland and thorny scrub.
2	Chacane - Panda	No further information other than the general conditions described for 1.
3	Panda Jangamo	Water table close to ground surface. Shown as 'lodo' on topographic map. Thorny scrub vegetation.
4	Mocodoene-Mavaume	The topography and drainage pattern as shown on the topographic map does not coincide with observation of higher ground to the east of this site. Site conditions indicate a flat, poorly drained site with very little vegetation other than grass, stunted trees, thorn and 'dwarf' palm (name unknown).
5	Funhalouro north	The ground seems to rise very gradually to the south of the borrow area (from field observations) though this is not borne out by the topographic map. Thorny scrub vegetation and grass. Dark brown silty fine sand overlying soil.
6	Track from EN1 to Magumbo village	On landward side of shoreline spit. Slope rises to west. Deposit is located at boundary between drained to the west and poorly drained to the east. Relatively minor contributing catchments. Soil is mid to dark brown silty fine sand.

Typical dark grey soil, sparse vegetation at calcrete borrow areas

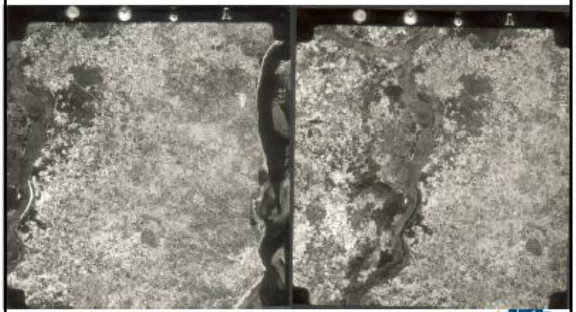
Remote Sensing Data Sources

- Black and white aerial photography for the entire Province at Cenacarta
- LANDSAT 7 satellite imagery downloaded from the USGS Earthexplorer website
- SPOT 5 available as on-screen view only on Google earth
- SPOT 5 for the eastern part of the Province as digital data at Cenacarta
- ASTER DEM downloaded from NASA

Note that the SPOT 5 at Cenacarta was not used as it only covered the eastern part of the Province

TRL

Phase 1 Desk Study: Stereo aerial photograph interpretation



Page • 7

The stereo aerial photography was very good at identifying subtle drainage features, including pans and drainage lines such as these

Outcome of the Stereo Aerial Photograph Interpretation

- The photographs were taken in the 1960s and are approximately 1:40,000 scale. However, even at this small scale, subtle differences in photograph tone and morphology could be picked out
- They have been spliced into sets of individual runs to produce linear mozaics which can be positioned relative to one another to yield an overall mosaic of most of the Province at an approximate scale of 1:90,000.
- Identification of pans and, where present, pan platforms
  - Very obvious recent pans and pan lakes close to the coast
  - More subtle pan features further inland.
- The terrain surrounding each of the existing borrow pits was examined to identify characteristic topography and drainage pattern.
- The interpretation allowed a terrain classification system to be developed.

Page • 9

Google Earth SPOT Image for Existing Borrow Pits 1 & 2

Google Earth SPOT Image for Existing Borrow Pit 3

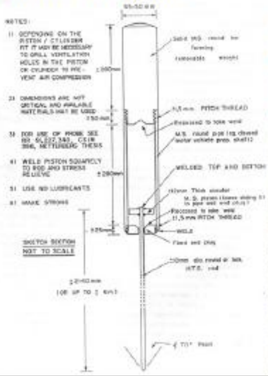
Visual Identification of Areas on Google Earth with Potentially the Same 'Reflectance' of the Existing Borrow Pits

Page • 12

Visual Identification of Areas on Google Earth with Potentially the Same 'Reflectance' of the Existing Borrow Pits

Phase 2 Fieldwork

Calcrete probe (Netterberg 1969)



Probe Refusal vs Material Type (Netterberg, 1978)

Penetration resistance	Point appearance		Calcrete type
Varies from almost none to refusal within a few square metres	No deposit if little resistance, white or pale pink colour on refusal	Cannot all	Loose sand interspersed with boulder calcrete
Refusal	White or pale pink colour	be rubbed	Hard hardpan or boulder, probably unpickable
High	White or pale pink colour	off with	Loose, hard nodular calcrete, stiff hardpan of calcified sand
High to fair	Pale mauve	the	Tufaceous hardpan
Fair to low	White	fingers	Powder calcrete
Low	White sandy deposit; can be rubbed off easily with the fingers		Calcareous soil

Outcome of the Phase 2 Fieldwork

Low-lying areas, predominantly in the central part of the Province, with poor drainage, grey soils (predominantly sands) and sparse vegetation, especially thorn, became the typical locations for positive probing results

Finding this thorn is not the problem – it usually finds you first!

Outcome of the Phase 2 Fieldwork

- A total of 48 locations were recorded (additional to the existing calcrete borrow areas) where either remote sensing, surface probing investigations or outcrop gave rise to the identification of calcareous materials.
- Of these
  - 13 were considered likely to be *in situ* Tertiary Limestone
  - 7 were considered likely to be Lacustrine Limestone, according to the outcrop pattern
  - 1 calcareous sandstone
  - 2 coralline material
  - 1 calcified sand
  - 1 embryonic calcrete
  - 23 calcrete

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Prioritisation of Phase 3 Fieldwork

- Trial pitting to be carried out by ANE (as described by Joana later) was scheduled at 10 priority locations out of the 23 calcrete prospects. Priority was based on distance from an existing source, and anticipated extent.

TRL

Phase 3 Fieldwork Results: Existing Calcrete Borrow Pits and Proven Prospects (see Geomorphological Map for Possible Explanation)

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Phase 2 Desk Study

- This was designed to build on the success of the Phase 3 Fieldwork by utilising 24 existing/proven calcrete deposits as a benchmark for identifying similar locations from satellite imagery:
- Visually (on screen) using Google Earth SPOT
- Digitally using ASTER DEM
- Digitally using multi-spectral analysis in LANDSAT

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Use of Google Earth Spot to Visually Characterise Existing/Proven Calcrete Locations and Extrapolate to other Possible Areas

Page • 25

Page • 26

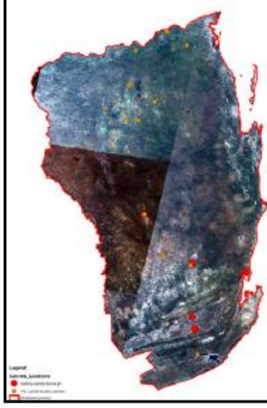
Page • 27

Page • 28

Further Prospects Identified for Probing Investigations

Northings			Eastings			Comment
Deg S°	Min'	Sec"	Deg E°	Min'	Sec"	
21	40	40.35	34	12	22.1	Centre line
21	45	38.45	34	10	34.03	East of road
21	47	45.77	34	11	1.03	Centre line
21	51	3.18	34	10	33.66	Centre line
21	54	16.22	34	25	48.94	Centre line
21	53	3.28	34	27	16.34	Centre line
21	51	44.77	34	28	17.89	West of road
22	4	3.65	34	14	22.23	South of road
22	2	57.44	34	8	13.53	East of road
22	9	24.66	34	1	9.99	Centre line
22	11	47.01	33	56	47.26	Centre line
22	10	47.69	33	50	8.82	South of road
22	36	3.23	34	17	28.73	Centre line
22	38	7.74	34	17	43.79	South of road
23	2	24.89	34	26	30.79	Centre line
22	58	17.03	34	28	24.06	Centre line
22	56	49.63	34	28	21.77	Centre line
24	10	35.32	34	24	38.65	East of road
23	15	42.41	34	27	29.95	Centre line
24	8	26.75	34	44	35.33	Centre line
24	7	27.56	34	44	13.34	Centre line
24	23	44.05	35	0	53.36	off road
24	25	41.12	34	54	14.48	off road
24	20	4.07	34	51	15.08	off road
24	27	12.46	34	52	25.93	off road
24	22	8.93	34	13	51.76	South of road
24	16	30.49	34	25	57.69	Centre line
24	21	49.26	34	14	7.33	South of road
23	30	39.19	34	38	16.56	Centre line
23	30	39.19	34	38	16.56	Centre line
23	30	50.45	34	40	53.95	South of road
21	24	46.21	34	17	55.36	West of road
21	23	12.3	34	24	24.57	North/South of road
21	22	51.02	34	26	51.96	Centre line
21	16	48.22	34	44	37.07	East of road
21	16	26.96	34	44	13.01	East of road

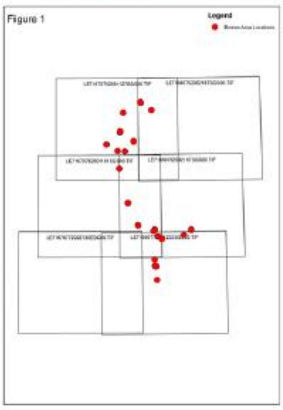
LANDSAT 7 (MSS Analysis)



The aim of the Landsat analysis (30m spatial resolution) was to attempt to locate previously unknown calcrete deposits using the pattern of spectral wavebands recorded at existing deposits (borrow pits and from field investigations)

LANDSAT tiles

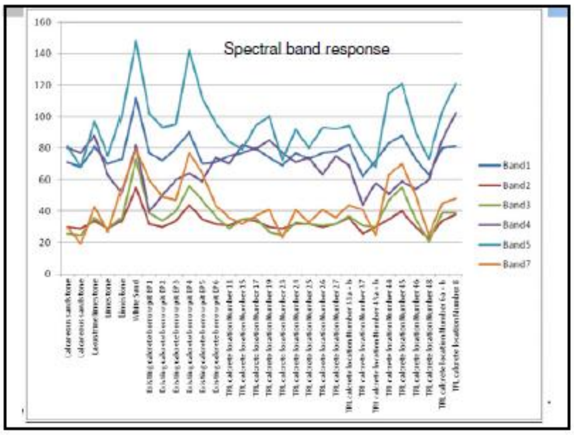
The Landsat 7 imagery tiles used in this study where downloaded from the USGS earthexplorer website. These tiles are the latest available 2001-2002 without cloud cover.

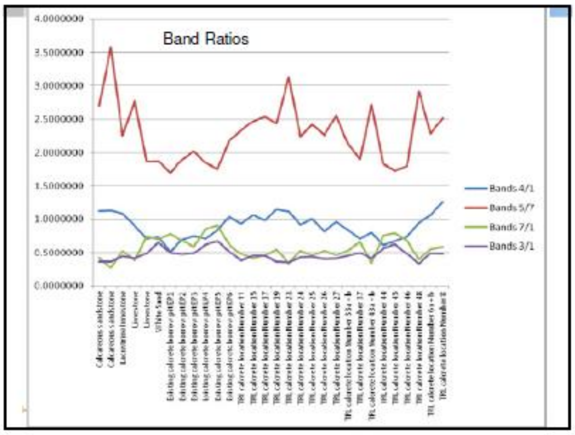


Page • 31

LANDSAT Spectral Bands

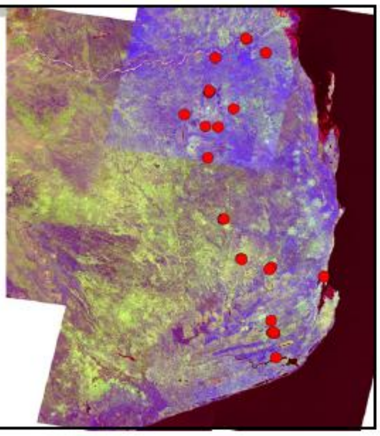
Band 1 (0.45-0.52 µm, blue-green) This short wavelength of light penetrates better than the other bands, & it is often the preferred band for monitoring aquatic ecosystems (sediment in water, coral reef habitats, etc.).	**Band 5** (1.55-1.75 µm, mid-infrared) This band is very sensitive to moisture and is therefore used to monitor vegetation and soil moisture. It is also good at differentiating between clouds and snow.
Band 2 (0.52-0.60 µm, green) This has similar qualities to band 1 but not as extreme. The band was selected because it matches the wavelength for the green we see when looking at vegetation.	**Band 6** (10.40-12.50 µm, thermal infrared) This is a thermal band, which means it can be used to measure surface temperature. Band 6 is primarily used for geological applications but it is sometime used to measure plant heat stress.
Band 3 (0.63-0.69 µm, red) Since vegetation absorbs nearly all red light (it is sometimes called the chlorophyll absorption band) this band can be useful for distinguishing between vegetation and soil and in monitoring vegetation health.	**Band 7** (2.08-2.35 µm mid-infrared) This band is also used for vegetation moisture although generally band 5 is preferred for that application, as well as for soil and geology mapping.
Band 4 (0.76-0.90 µm, near infrared) Since water absorbs nearly all light at this wavelength water bodies appear very dark. This contrasts with bright reflectance for soil and vegetation.	





Colour composite Carbonates shown as magenta

Note that different LANDSAT tiles give different spectral signatures, compounding the difficulty

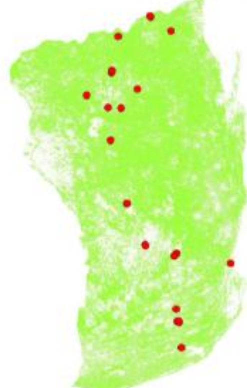


Page • 35

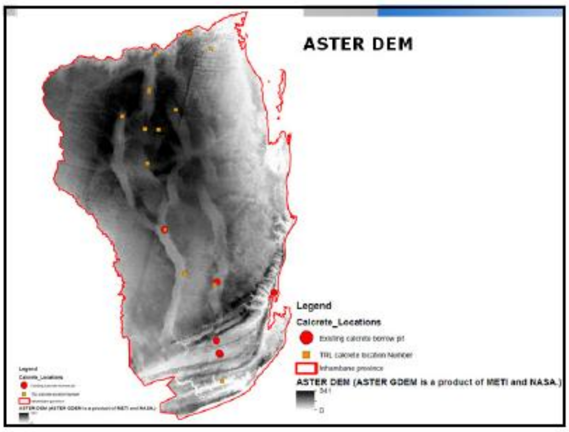
Conclusions from the LANDSAT Analysis

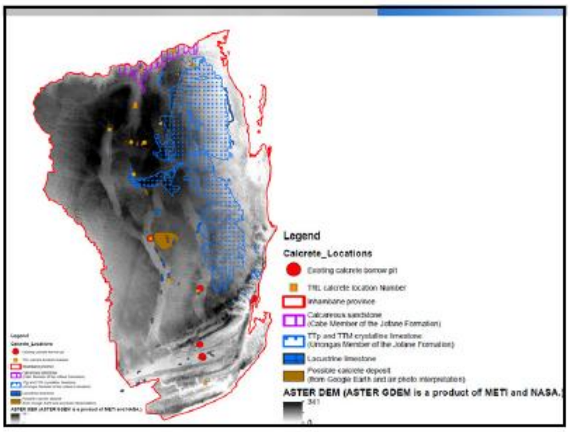
3:1 Band Ratio

There is no correlation between the band ratios and calcrete locations. There is also no spectral response that can be used to distinguish the calcrete locations and the other known geology units.



Page • 36


ASTER DEM
Legend
Calcrete_Locations
Existing calcrete borrow pit
TRL calcrete location Number
Inhambane province
ASTER DEM (ASTER GDEM is a product of METI and NASA.)
341
0


Legend
Calcrete_Locations
Existing calcrete borrow pit
TRL calcrete location Number
Inhambane province
Calcareous sandstone (Cabe Member of the Jofane Formation)
TTp and TTM crystalline limestone (Urrongas Member of the Jofane Formation)
Lacustrine limestone
Possible calcrete deposit (from Google Earth and air photo interpretation)
ASTER DEM (ASTER GDEM is a product of METI and NASA.)
341
0

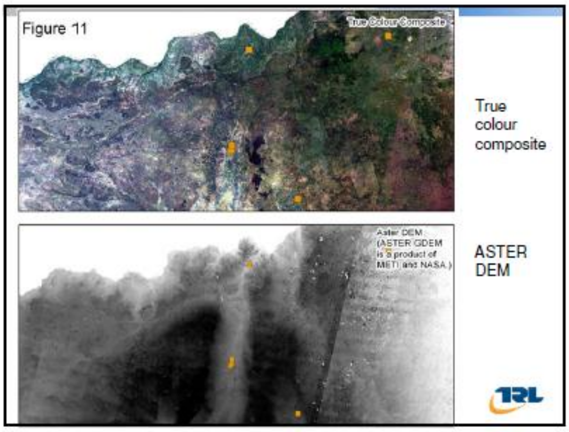
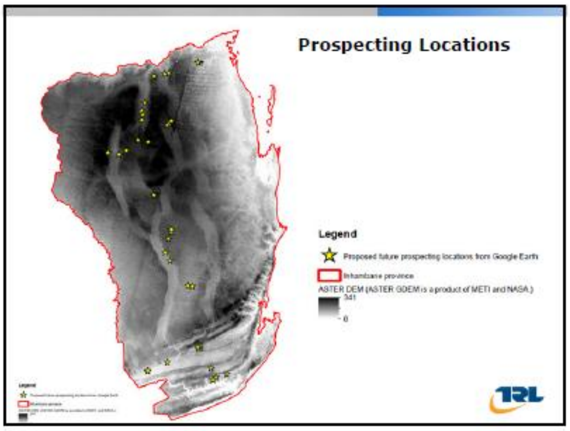
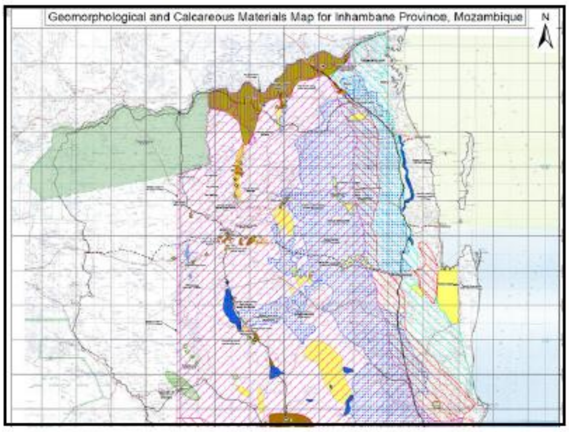
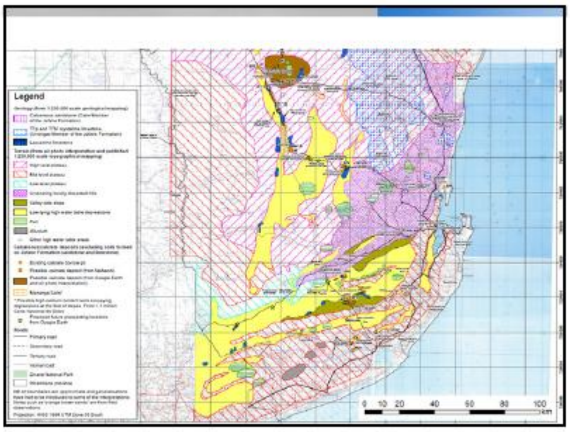
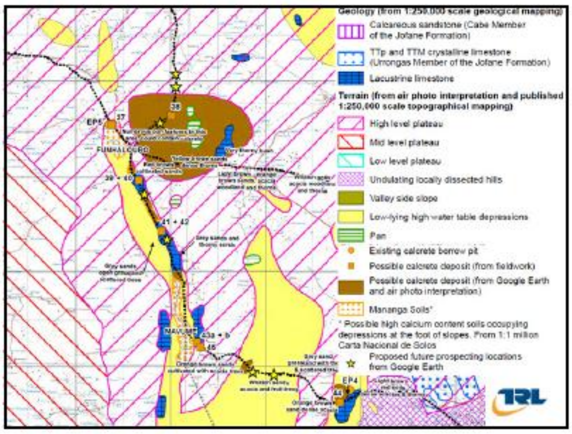


Figure 11
True Colour Composite
True colour composite
Aster DEM (ASTER GDEM is a product of METI and NASA.)
ASTER DEM


Prospecting Locations
Legend
Proposed future prospecting locations from Google Earth
Inhambane province
ASTER DEM (ASTER GDEM is a product of METI and NASA.)
341
0


Geomorphological and Calcareous Materials Map for Inhambane Province, Mozambique
N


Legend
0 10 20 40 60 80 100

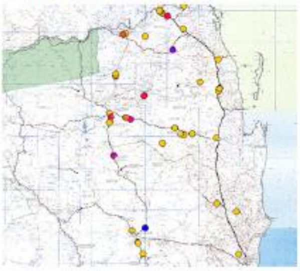


Special Thanks:

- Joana Guiele, ANE
- Francisco Manheche, ANE
- Óscar Francisco, ANE
- Lino Jorge Caixane, ANE
- All remote sensing and mapping staff at Cenacarta, Maputo
- Staff at the Ministry of Mineral Resources, Maputo
- Camila de Sousa, Institute of Agriculture (IIAM)
- Frank Netterberg, Pretoria

GIS and Database Management

Location Details

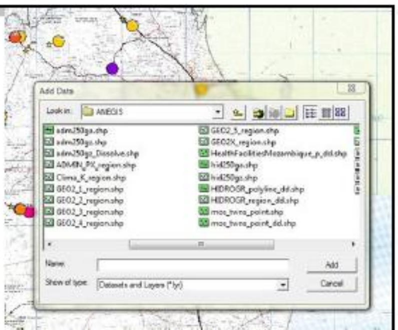


The GIS links to the database, enabling the latest information to be displayed. Here the potential sites are shown colour coded by their priority score

Page • 46

GIS

GIS Layers

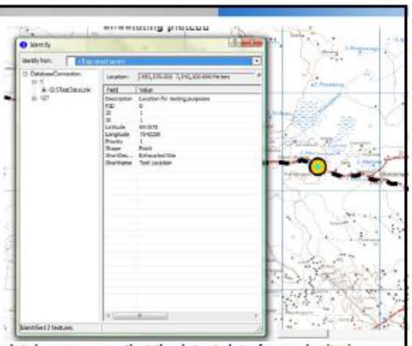


Being a standard ArcMap project, layers obtained from other sources can also be added to the GIS.

Page • 47

GIS

Database Linking

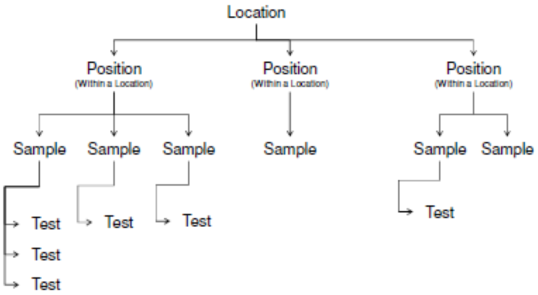


The live link to the database means that the latest data for each site is always available.

Page • 48

Database Management

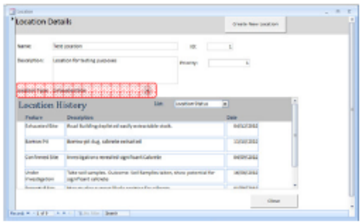
Database Design



Page • 49

Database

Location Details

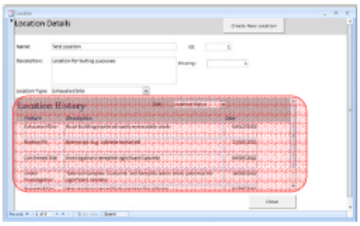


Locations have a status assigned, which shows if they are potential or actual sites. Sites which have been exhausted or discounted are also included to allow them to be excluded from future investigations.

Page • 50

Database

Location Details

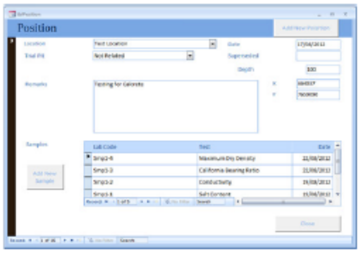


The history allows the previous status of the location to be easily checked.

Page • 51

Database

Positions

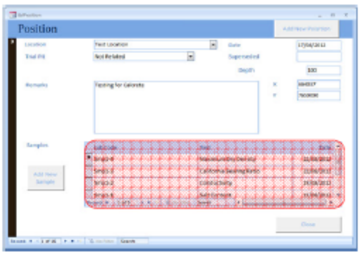


Within each location, a number of positions can be defined. These are the places where test samples have been collected.

Page • 52

Database

Positions

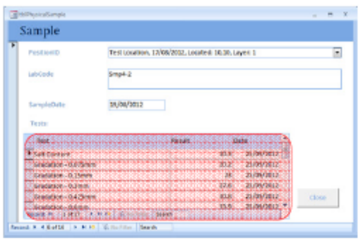


The individual samples collected and the tests which they have undergone are listed.

Page • 53

Database

Samples



Each sample can then have one or more tests carried out and the results recorded.

Page • 54

Trabalho de campo realizado no ambito do estudo
By Joana Guiuele

Identificação e Mapeamento dos Depósitos de Calcário na Província de Inhambane

Vilanculos– Hotel Águia Negra 14-15 de Março de 2013

TRABALHO DE CAMPO REALIZADO NO ÂMBITO DO ESTUDO

02-04-2013 2

Conteúdo da Apresentação

1. Descrição do trabalho de campo realizado;
2. Procedimentos para identificação do material;
3. Procedimentos para a colheita de amostras;
4. Imagens de locais de ocorrência do calcário;
5. Plantas geralmente encontradas nos locais de ocorrência de calcário;
6. Constrangimentos;
7. Conclusões.

02-04-2013 3

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1. Descrição do Trabalho de Campo Realizado

- Foram efectuadas visitas às câmaras de empréstimo existentes (Inhassune, Chivalo e Mawaela no Distrito de Panda; Mavume-Distrito de Funhalouro, Funhalouro sede-Distrito de Funhalouro, Manhaussane, Massalane, Chindjinguire, Mubalo e Domodomo no Distrito de Homoine; Coa, Save, Maluvane e Jofane no Distrito de Govuro; Pambara no Distrito de Vilankulo);

- Foi feita investigação das zonas de ocorrência do calcário ao longo de toda Província de Inhambane, principalmente nas estradas classificadas (prospecções, colecta e testagem do material);

02-04-2013 4

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1. Descrição do Trabalho de Campo Realizado- cont.

- Foram realizadas visitas a cerca de cem locais (100), dentre os quais quarenta e oito (48) foram os que apresentaram material calcário (excluindo as câmaras existentes).

- Das 48 câmaras, dez (10) foram priorizadas para efeitos de estudo, onde foram colhidas amostras para realização de testes laboratoriais no LEM, ANE Inhambane e algumas na África do Sul.

A tabela de prioridades é conforme abaixo ilustrada.

02-04-2013 5

No	Nº da Estrada	Nome da Estrada	Coordenadas	Meio de verificação usado	Resultados obtidos com Probe (profundidade)	Material Provável	Prioridade de Investigação (PIR) 1 prioridade
			Graus/Min				
5	N222	Mapinhane-Mabote	22°05.620'/34° 19.230'	Observação visual no terreno	1.1m	Calcário	7
6a	N222	Mapinhane-Mabote	22°04.863'/34° 08.043'	Observação visual no terreno	0.45m e 0.75m	Calcário	2
6b	N222	Mapinhane-Mabote	22°04.874'/34° 16.821'	Observação visual no terreno	1.0-1.3m	Calcário	2
8	R481	Mabote - Tome	22°04.526'/34° 08.811'	Observação visual no terreno	0.3m	Calcário	6
11	R481	Mabote – Tome	22°24.243'/34° 10.436'	Observação visual no terreno	Não foi feita prospecção com probe	Lacustrine limestone ou calcário (hard pan)	8
15	N1	Vilankulos – Save	21°18.217'/34° 46.874'	Observação visual no terreno	1-1.5m	Calcário?	5
21	R457	Pande - Jofane	21°29.121'/34° 41.574'	Identificado no GoogleEarth	1.0 e 1.2m	Calcário?	9

02-04-2013 6

No	Nº da Estrada	Nome da Estrada	Coordenadas	Meio de verificação usado	Resultados obtidos com Probe (profundidade)	Material Provável	Prioridade de investigação (1-10) 1- prioridade alta
			Graus/Min				
23	R457	Jofane turnoff - Zinave	21°21.406'/34°15.049'	Observação visual no terreno	Não foi feita prospecção com probe	Calcário	3
33a	R921	Crz N1 – Cometela – Mussengue – Mabote	21°53.375'/34°26.621'	Observação visual no terreno	0.9m	Calcário	4
33b	R921	Crz N1 – Cometela – Mussengue – Mabote	21°53.478'/34°26.420'	Observação visual no terreno	0.9m	Calcário	4
38	R481	Funhalouro - Tome	23°01.587'/34°27.828'	Observação visual no terreno	Não foi feita prospecção com probe	Lacustrine limestone ou calcário (hard pan)	10
43a	R902	Mavume - Mocoduene	23°27.454'/34°31.351'	Observação visual no terreno	0.9m	Calcário	1
43b	R902	Mavume - Mocoduene	23°27.767'/34°31.934'	Observação visual no terreno	0.6m -0.7m	Calcário	1

02-04-2013 7

2. Procedimentos para identificação do material

Foi usada um equipamento de sondagem de calcário "calcrete Probe" para determinar a profundidade do material existente em cada local de ocorrência de calcário.

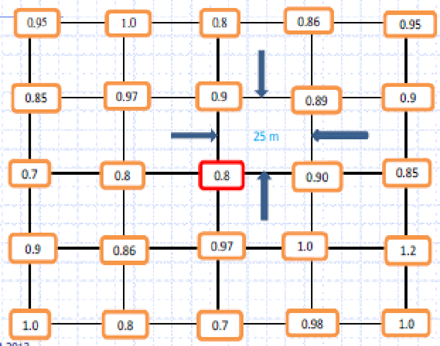
02-04-2013 8

3. Procedimentos para Colheita de Amostras

- Foram feitas prospecções com uso do Probe de 25 em 25 m numa área de (100 x 100) m, conforme abaixo ilustrado.

02-04-2013 9

Prospecções feitas com o probe de 25 em 25 metros



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3. Procedimentos para colheita de amostras- cont.

- Em cada área escavou-se um furo no centro com dimensões (1m Larg. x 2m Comp. x2 m <prof.)
- A amostra foi colhida de acordo com a dureza do material:
  - Colheita da camada dura do calcário "hard pan" – pode ser esmagada com um martelo
  - Colheita do Calcário nodular – pode ser esmagada com uma pressão firme dos dedos;
  - Colheita da camada do calcário em pó – facilmente esmagada com uma leve pressão dos dedos.

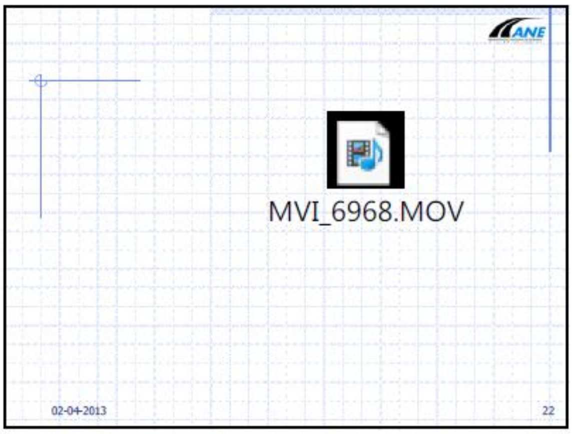
O material colhido era armazenado em sacos plásticos e selado para envio ao laboratório

02-04-2013 11

4. Imagens de locais de ocorrência do calcário

02-04-2013 12


Imagens de locais de ocorrência do calcário (câmaras)
14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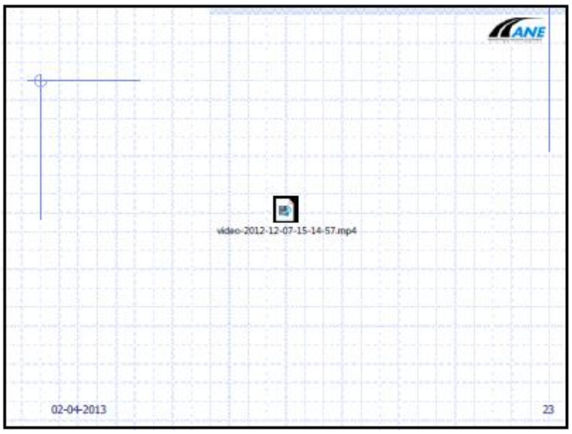
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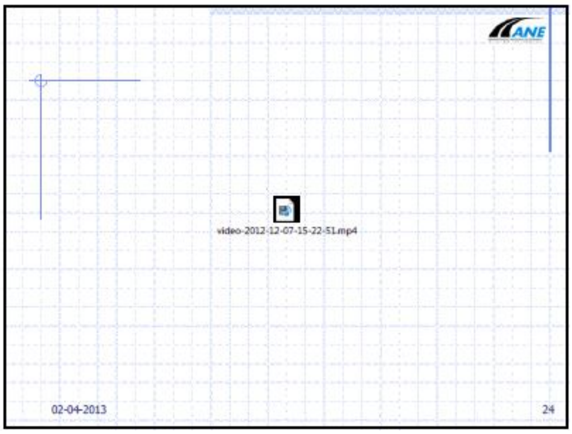
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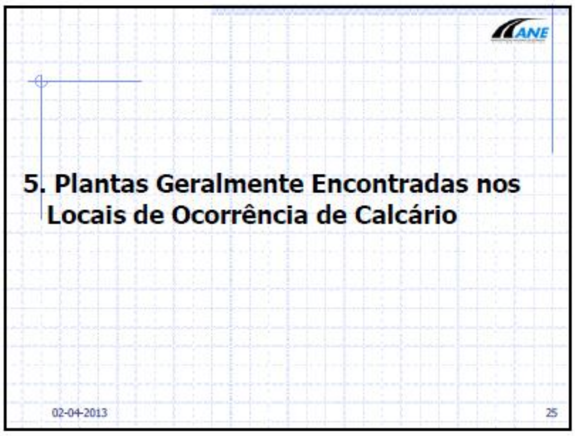
24


5. Plantas Geralmente Encontradas nos Locais de Ocorrência de Calcário
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25


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02-04-2013
37

Calcrete project: Trial pit investigations in Mozambique

By Francisco Manheche

ANE PRESENTATION

CALCRETE PROJECT
TRIAL PIT INVESTIGATIONS
IN MOZAMBIQUE

CONTENTS

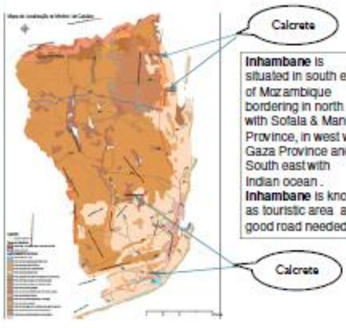
1. INTRODUCTION OF CALCRETE PROJECT IN MOZAMBIQUE
2. WHAT IS CALCRETE?
3. PURPOSE SCOPE OF PROJECT
4. TRIAL PIT INVESTIGATION
5. CONCLUSION & RECOMENDATION

INTRODUCTION

- Mozambique has serious shortage of road building materials, in particular, in Inhambane
- Materials for the construction of bases are very poor in most areas, e.g. fine coastal sands covering most of eastern Mozambique
- It is even more difficult to find surfacing aggregate in Inhambane .
- It is ABSOLUTELY necessary to develop alternative solutions using local materials such as calcrete, which is available in Inhambane Province. RRIP and the AFCAP project is using calcrete for road construction.

WHERE INHAMBANE IS SITUATED?

Inhambahe is one Province in Mozambique is situated in the South Eastern Africa, bordering in the North with Tanzania, in the West with Malawi, Zambia, Zimbabwe, Swaziland, in the South with South Africa, and in the East with the Indian Ocean.



Inhambane is situated in south east of Mozambique bordering in north with Sofala & Manica Province, in west with Gaza Province and in South east with Indian ocean . **Inhambane** is known as touristic area and good road needed.

PURPOSE SCOPE OF PROJECT

Provide guidance to ANE on the location of calcrete deposit, as well as on the classification of road building material and find out the appropriate technical specification for using in road construction.

WHAT IS CALCRETE?

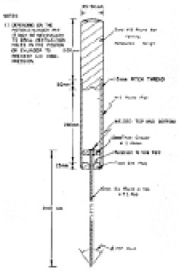
- Calcrete can be regarded as a material formed by the *in situ* cementation and/or replacement of almost any pre-existing soil by calcium carbonate deposited from the soil or ground water.


Calcrete borrow pit in Inhambane

TRIAL PIT INVESTIGATION

- The criteria for selection of borrow area was made by:
- Look for vegetation(botanical) and searching the existence of calcrete with an instrument similar to DCP equipment **(PROBING DEVICE)** . Later acid help to identify.
- The borrow chosen was not be too close to the existing borrow areas.
- total of 3 borrow was be sampled for lab testing.
- 3 test pit were dug per borrow area

How we identify calcrete in the ground?



RAPID CALCRETE PROBING DEVICE:

It is an instrument similar to a DCP equipment.

Identification of calcrete in the ground and Borrow pit

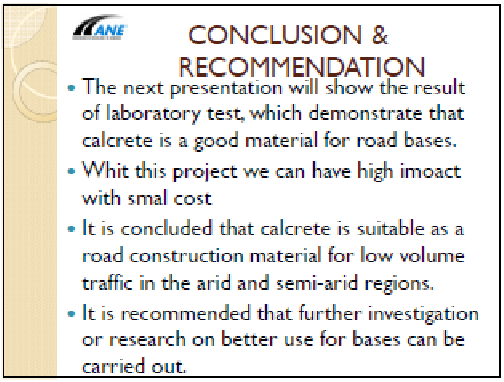
- BORROW PIT LAY OUT
- I II III IV
- I X X X X
- 2 X X X X
- 3 X X X X
- 25m
- 100X100 m

What kind of test is needed?

- Grading
- Atterberg limits
- Compaction/CBR
- Conductivity (P425) salt content needs to be determined
- 10% FACT on hardpand/boulder calcrete samples

WHERE WAS THE TEST CARRIED OUT?

- The test was carried out in ANE laboratories at Inhambane and Maputo,
- Another test was carried out in LEM (Laboratorio de Engenharia de Moçambique).
- Same of materials went to south Africa.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CONCLUSION & RECOMMENDATION
• The next presentation will show the result of laboratory test, which demonstrate that calcrete is a good material for road bases.
• Whit this project we can have high imoact with smal cost
• It is concluded that calcrete is suitable as a road construction material for low volume traffic in the arid and semi-arid regions.
• It is recommended that further investigation or research on better use for bases can be carried out.


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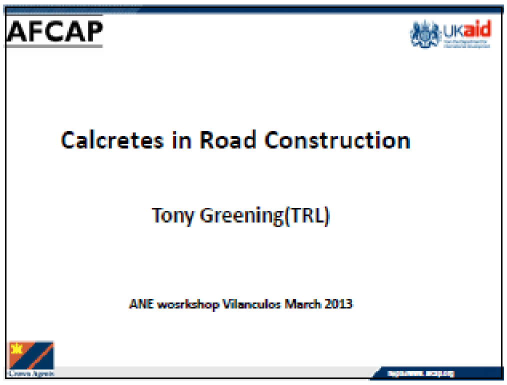
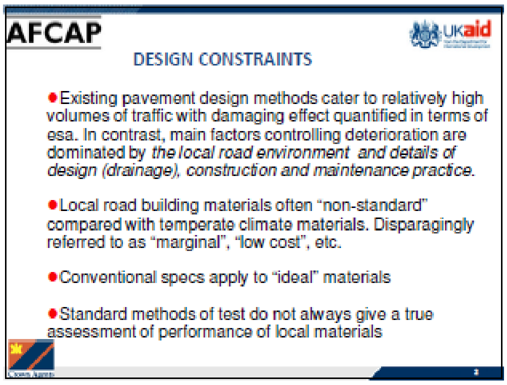
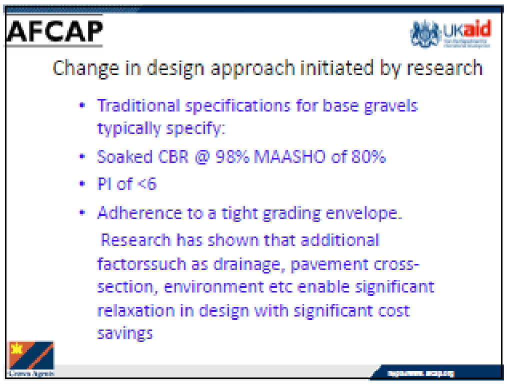
Thank You!

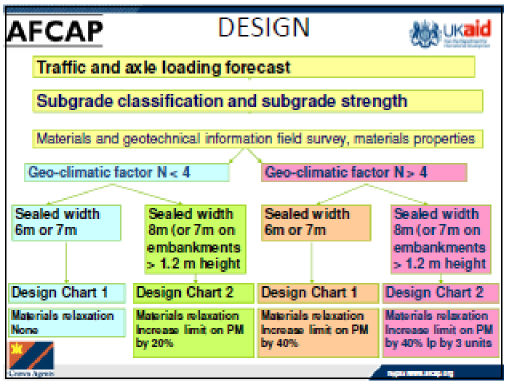
Calcretes in road construction

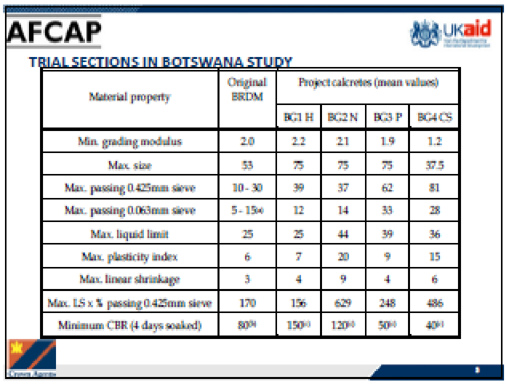
by Tony Greening



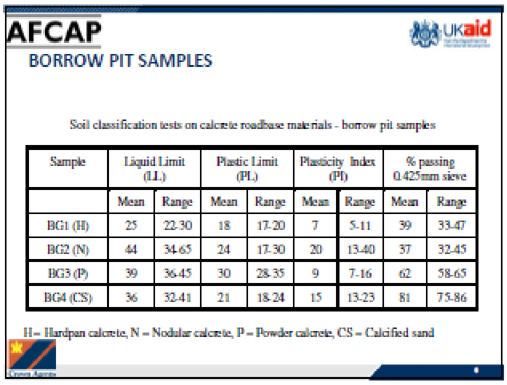








Material property	Original BRDM	Project calcretes (mean values)			
		BG1 H	BG2 N	BG3 P	BG4 CS
Min. grading modulus	2.0	2.2	2.1	1.9	1.2
Max. size	53	75	75	75	37.5
Max. passing 0.425mm sieve	10 - 30	39	37	62	81
Max. passing 0.063mm sieve	5 - 15	12	14	33	28
Max. liquid limit	25	25	44	39	36
Max. plasticity index	6	7	20	9	15
Max. linear shrinkage	3	4	9	4	6
Max. LS x % passing 0.425mm sieve	170	156	629	248	486
Minimum CBR (4 days soaked)	80	150	120	50	40



Soil classification tests on calcrete roadbase materials - borrow pit samples

Sample	Liquid Limit (LL)		Plastic Limit (PL)		Plasticity Index (PI)		% passing 0.425mm sieve	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
BG1 (H)	25	22-30	18	17-20	7	5-11	39	33-47
BG2 (N)	44	34-65	24	17-30	20	13-40	37	32-45
BG3 (P)	39	36-45	30	28-35	9	7-16	62	58-65
BG4 (CS)	36	32-41	21	18-24	15	13-23	81	75-86

H = Hardpan calcrete, N = Nodular calcrete, P = Powder calcrete, CS = Calcified sand

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SAMPLES FROM THE ROAD (BOTSWANA TEST SECTIONS

Material	Section	Average CBR[a]			Ratio	
		4-day soaked	At OMC	Dried back	Optimum/ Soaked	Dried/ Soaked
BG1 – H	8	80 (24)	90 (7)	190 (67)	1.1	2.4
BG2 – N	4	85 (41)	140 (27)	250 (24)	1.6	2.9
BG3 – P	1	60 (9)	75 (9)	120 (12)	1.3	1.6
BG4 – CS	3	23 (12)	90 (11)	200 (40)	3.9	10.0

7

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12 TEST SECTIONS IN BOTSWANA MONITORED FOR 12 YEARS

Section	Roadbase	Sub-base	Surfacing
A	Weathered granite gravel	Ferruginous gravel	DSD
1	BG3 - powder calcrete	Kalahari sand	DSD
2	BG3 - powder calcrete (compacted dry)	Kalahari sand	DSD
3	BG4 - calcified sand	Kalahari sand	DSD
4	BG2 - nodular calcrete	Kalahari sand	DSD
5	BG2 - nodular calcrete (dried after construction)	Kalahari sand	DSD
6	BG2 - nodular calcrete (reconstructed)	Kalahari sand	SS
7	BG3 - powder calcrete (reconstructed)	Kalahari sand	SSD
8	BG1 - hardpan calcrete	Kalahari sand	DSD
B	Crushed quartz gravel	Ferruginous gravel	SS
C	Crushed quartz gravel	Ferruginous gravel	SSD
D	Crushed quartz gravel	Ferruginous gravel	DSD

8

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SPECIFICATIONS FOR CALCRETE BASES (GREENING AND ROLT)

Property	Maximum traffic (ESA x 10^6)				
	0.3	0.5	0.7	1.0	1.5
Maximum particle size (mm)	75	75	75	75	75
Max % passing 0.425mm sieve	80	65	65	45	30
Max % passing 0.063mm sieve	30	30	25	20	15
Maximum liquid limit	60	55	50	40	30
Maximum plasticity index	25	20	15	12	10
Maximum linear shrinkage (%)	12	12	8	6	5
LS x % passing 0.425mm sieve	800	700	550	400	200
LS x % passing 0.063mm sieve	300	300	300	200	100
Minimum soaked CBR[1]	40	50	60	60	80

9

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CALCRETE IN BITUMNOUS ROAD BASES NETTERBERG)

Property[1]	Expected traffic category, vpd, <20% > 3 tonnes			
	< 500	500 - 1000	1000 - 2000	2000 - 5000
Max. size (mm) Min. Grading Modulus[2] % passing 0.425 mm by mass	19 – 38 1.5 15 - 55	38 – 53 1.5 15 – 55	38 – 53 1.5 15 – 55	38 – 53 1.5 15 – 55
Max. Liquid Limit (%) Max. Plasticity Index (%) Max. Bar Linear shrinkage (%)	40 15 6.0	35 12 4.0	30 10 3.0	35 8 3.0
Max. Sat. Paste Elec. Cond.[3] (S/m @ 25°C	0.15	0.15	0.15	0.15
Max. Group Index Worst ASTM D 3282 class Max. Bar Lin. Shrinkage x % < 0.425 mm	0.5 A-2-6 320	0.0 A-2-4 170	0.0 A-2-4 170	0.0 A-2-4 170
Min. Dry 10% FACT[4] value (kN) or Max. Dry Aggregate Crushing value (%) Min. Soaked/Dry 10% FACT value (%) Max. Water Absorption (%) Min. Dry Aggregate Pliers Value (%)	50? 40? 50? - 50?	80? 35? 50? - 60?	110? 30? 50? 5? 70?	110? 30? 50? 5? 70?
Min. 98% Mod. AASHO 0.1" CBR (%) Min. 98% Mod. AASHO 0.2" CBR (%) Max. Mod. AASHO Swell (%) Min. relative Field Comp. % Mod.	60 80 0.5 98	80 80 0.5 98	80 100 0.5 98	80 100 0.5 [illegible]

10

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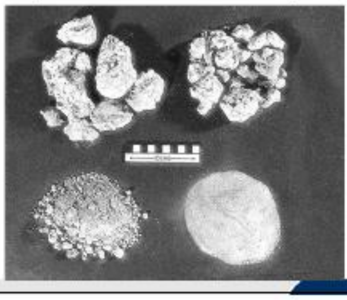
EXAMPLES OF TYPICAL TYPES OF CALCRETE USED IN ROAD (ALL SOMETIMES FOUND IN ONE B.P)



11

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Materials Compliance

- It was only possible to undertake one series of tests per single sample from a test pit 2m deep in each borrow pit.
- The inherent variability of calcrete, coupled with the very poor reproducibility of the CBR test, make a single result unreliable.
- The lack of compatability of the calcrete specifications which were derived from BS test standards with the actual laboratory testing which was carried out using South African TMH1 test standards.

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Test Results

- There is clearly a high degree of variability in some of the test results which make the comparison with existing specifications difficult.
- This is exacerbated by the use of different test methods. (apples and oranges)
- The quality of calcrete deposits is highly variable both with depth and area. Single-sample testing is highly unreliable.

AFCAP

Summary of test results

- Some of the borrow pits located, namely Mavume (LEM 07-V), Mabote (LEM 09-V) and Save (LEM04-V) contain calcrete that appears to be potentially suitable for use as base course, subbase and selected fill of low volume roads carrying less than 0.3 million ESAs.
- The remaining borrow pits contain calcrete that appears to be suitable for subbase and selected fill for low volume roads carrying less than 0.5 million ESAs..
- The hard pan calcrete appears to be suitable for used as surfacing aggregate or as crushed stone base course.
- Salinity does not appear to a problem.
-

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Suitability of calcretes for road construction in Inhambane

- The terms of reference require an evaluation of the suitability of existing systems to classify the Inhambane calcretes based on a review of existing test data.
- The inconclusive nature of the results make such an evaluation impossible.
- The current calcrete classification system has been developed on the basis of many years of research work.
- It will require a commprehensive investigation of calcretes in Inhambane province to provide the data necessary to evaluat the suitability of the current calcrete classification systems.

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Conclusions

On the basis of the limited samples tested to date and the specification adopted:

- All of the materials tested would be suitable for gravel wearing course and sub-base.
- At least 3 samples would be suitable for roadbase in a LVR (sealed shoulders?)
- At least one sample collected appeared to be (hard) and thus possibly suitable for use in Otta seals or other surfacing options.

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Pavement design and materials

Using local materials

The art of the roads engineer consists for a good part in utilising specifications that will make possible the use of materials he finds in the vicinity of the road works.

Unfortunately, force of habit, inadequate specifications and lack of initiative have suppressed the use of local materials and innovative construction technologies"

→Consider materials' "fitness for purpose"

→Make specification fit materials rather than materials fit specification

This approach needs to be supported by research

AFCAP

PERFORMANCE OF LOW-VOLUME ROADS

Many low-volume roads have performed better than expected.
Is this due to:
Overdesign (too conservative)?
Environmental factors?
Timely maintenance?
The actual traffic damage is less than forecasted?
(i.e the exponent of 4.5 is inappropriate)
Good construction practice?
All of these and more?


AFCAP
Botswana Trans-Kalahari Highway
UKaid
Before
After
New laboratory tests and specifications for sand as sub-base material
Use of 'marginal' materials for road base
Provision of sealed shoulders enabling use of weaker materials
Revised specifications and techniques allowing use of weaker aggregates for surfacing
SAVINGS > US$20 million


AFCAP
UKaid
THANK YOU

Mozambique AFCAP/RRIP research on use of calcrete in Inhambane province
by Kenneth Mukura

Moz AFCAP/RRIP Research on use of Calcrete in Inhambane Province

Presentation by Kenneth Mukura

Introduction

- Mozambique is a large country with a relatively small road network
- More than 70% of the network is unsealed
- Good road construction materials are scare (e.g. haul distances of surfacing aggregate may exceed 400km)
- Vast areas are covered in coastal sands
- Previous research carried out by TRL and ANE showed an average rate of gravel loss on unpaved roads exceeding 50mm/year (maintenance demand is high)

Page • 2

Issues relating to Inhambane

- **Shortage of materials**
  - Natural local material that can be used for base and surfacing is calcrete
  - Red and grey sands are abundant but usually used for construction of cement stabilised bases (CTB)
- **High costs**
  - Expensive to build roads, especially Low Volume Roads
  - Use of locally available calcrete will reduce costs significantly

Page • 3

Research work under AFCAP/RRIP

- ANE initiated the Rural Road Investment Programme (RRIP) supported technically by AFCAP: Phase 1 from 2008, Phase 2 from 2009, Phase 3 from mid-2011.
- More than 50km have been built and Otta seals constitute the bulk of the sections
- Designs also include concrete slabs and stone paving with concrete screed on steep ramps, emulsion treated bases, armoured bases, slurry seals, sand seals, penetration macadam, untreated sand bases, etc
- Designs were carried out by TRL and provincial consultants (Stange in Inhambane). Construction is carried out mostly by local contractors
- ASDI (SIDA) provided funding for construction works and DFID is providing funding for technical support

Page • 4

Inhambane: Cumbana Chacane Road

Section	Description	Remarks
Section 1 Unpaved (6km)	Blended wearing course 50:50 calcrete and sand	Performance based specifications developed by TRL were used
Section 2 and 3	Blended base 50:50 calcrete and sand with Otta seal	Resultant base with CBR=40%, Calcrete graded aggregate with norminal size of 13mm ACV=25.4. Binder rate 1.2, 1.5, 1.6, 1.8, 2.0, 2.4 L/m2
Section 4	Armoured base with sand seal	100 – 120mm neat sand base + layer of aggregate 20-40mm (50mm max)
Section 5	Neat sand base with penetration macadam surfacing	Red sand (CBR=26-36), penetration macadam 1st layer (20-40mm) second layer of 5-13mm or sand.

Page • 5

Cumbana Chacane Road – Blending Before and after intervention

Page • 6

Inhambane: Cumbana Chacane Road

Cumbana Chacane Road –calcrete aggregate

Cumbana Chacane Road – calcrete Otta seal

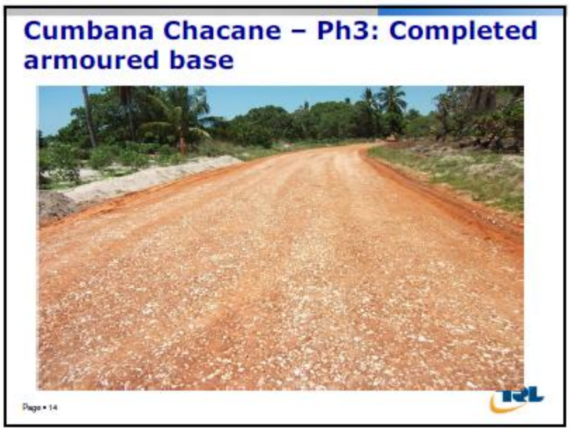
Cumbana Chacane – most sections performing well – Ph2

Challenges

- The calcrete had too much powder (dust) and the dust was covering the binder before the aggregate landed.
- The binder distributor was brand new but it was spraying badly – recommended for it to be converted into a water bowser.
- ACV was good < 26 but there a small percent of weak aggregate
- Due to low traffic volumes extended rolling of the Otta seal was required (compensatory rolling) to aid curing of the surfacing
- The contractor did not correct the construction defects during the defects liability period

Cumbana Chacane – Ph3: Employment creation


Cumbana Chacane – Ph3:
Construction of armoured base


Cumbana Chacane – Ph3: Completed
armoured base


Cumbana Chacane – Ph3: Completed
armoured base


Cumbana Chacane – Ph3: Sand seal
over armoured base


Cumbana Chacane – Ph3: Sand seal
over armoured base


Cumbana Chacane – Ph3:
'Amalgamated surfacing'

Challenges

- Distributing the aggregate evenly on the full width of carriageway
- Getting adequate compaction
- Ensuring that the aggregate protrude above the fine material
- Construction was too slow – too long before second layer of sand was applied

Page • 19

Zambezia: Zero Mopeia Road

Page • 20

Recommendations

- Blended and armoured bases are viable solutions. Minimum requirements for the soaked CBR for low volume roads (CBR>40?)
- Otta seals cured very well for the finer aggregate even at low traffic volumes
- The blended wearing course has performed very well (no maintenance grading for 2 years and very low rate of gravel layer) – the performance based specifications are key to good practice
- Need to improve quality of construction
- Need for long term monitoring
- Need to minimise construction and LC costs

Page • 21

OBRIGADO