Caves, Sea Levels, and Sand Dunes: Applying 3D GIS to South African Archaeology

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Archeologists working along the South African southern coast use multidimensional GIS applications to model Pleistocene caves and paleo-environments reconstructing the landscape ca. 420,000 to 30,000 BP.

Although archaeology is a discipline traditionally associated with shovels, screens, and bags of artifacts, archaeologists are making more effective use of GIS to create precise maps of both small and large-scale landscape features thus bringing better environmental and regional contexts to their research. As archaeologists continually broaden their research agendas to include new interdisciplinary analytical and digital techniques within archaeology, GIS provides a unique platform to organize and analyze vast amounts of diverse archaeological data useful to create models of paleo-environment and archaeological sites.

The Site in Context
Mossel Bay Archaeology Project (MAP) has been excavating in a series of caves and rock shelters along the southern coast of South Africa, near Mossel Bay, Western Cape Province. MAP excavates these caves in order to understand more about the origins and behavior of modern *Homo sapiens* – where and how our species evolved as well as the ecological setting. An important component to this mission is reconstructing the environmental context. To accomplish the latter, MAP archaeologists created a multidimensional model of one of the caves (named 13F) and mapped its geologic features that related to sea level change and dune formation. Data collected at 13F were used to model the changing character of these ancient sea levels and sand dunes, and in turn help us understand the adaptive and behavioral strategies of the early *Homo sapiens*.

For this project, several data sources were created to map the cave features and paleo environments. These sources include coordinate data used to create the rasterized multidimensional model of the cave and polygonal cave features, as well as the integration of local geological observations including geologic dating techniques (e.g. Uranium series dating).

Making the Model
The model of cave 13F has two primary components: 1) coordinate points used to create the cave model and geologic features (with X, Y, Z data) and 2) extrapolated environmental features which include modeled dunes and sea levels. Particular emphasis was placed on collecting the first component during the 2004 field season – the coordinate data points – as the latter component can be modified outside of a field setting.

The coordinate points data set comprised 908 points that were collected over a period of 4 days using a reflectorless total station and a handheld computer. Coordinate data was processed initially using TDS SurveyPro software and then integrated into ESRI ArcGIS 9 where it was organized into thematic shapefiles representing geologic features and elevation modeling points. The cave itself was modeled using a clam-shell approach based on two digital elevation models. In effect, the cave floor was created as a positive elevation surface whereas the cave walls were modeled as a negative, or inverse, elevation surface (Figure 1).

Coordinate points were shot directly onto the surface of specific geologic features (i.e. mapping the perimeter of each feature and noting the paleosurface where applicable) as well as the rock itself. Geologic features – which included cemented dune, flowstone (further classified by color and texture), and calcretions – were later tied into the summary of the geologic history of the cave. For example, on the cave walls substantially above modern sea level are calcium carbonate formations secreted by marine organisms that live just below mean sea level. Once dated, these mapped deposits can be used to model ancient sea levels quite precisely, which then allows us to reconstruct the nature of the coastal terrain far in the past. The second component – extrapolated environmental features – used the mapped coordinate points as the basis for modeling paleo-dune surfaces.

The cave roof provided an exceptionally difficult surface to accurately model because it has a high degree of topographic relief and several prominent surfaces contain vertical walls and overhangs. Once the cave roof model was completed it was clipped to conform to the cave floor surface and mouth of the cave.

Once the GIS model of the cave itself was created, the geologic features were modeled by assigning X,Y, and Z coordinates to polygon nodes based on features' perimeters, producing a 3D effect. These geologic features are important to archaeologists as they are the material sampled to determine specific chronological ages associated with different episodes in the cave. For example, results from geologic dating indicate that there was a high sea level represented at Marine Isotope Stage 11 (~400,000 years ago) and 5e (beginning ~130,000 years ago) (Figure 2). Additional geologic dating indicate that dune deposits were present in the cave near the end of MIS 6 (ending ~130,000 years ago) and after MIS 5d-4 (115,000-60,000 B.P.).

Models of paleo-dunes were based on the surface remnants of cemented dunes mapped in the cave. Based on the angle of repose and the assumed paleo-surfaces, the top of the cave might have been open for certain periods during its geologic history. This technique of modeling the paleo-dunes can be applied to bigger geographic areas to model large-scale landscapes in the immediate area. As moving, dynamic pieces of the landscape, sand dunes would have played an important role in the South African cave systems as dune episodes alternatively sealed and opened the caves during different parts of the Pleistocene. Specifically, this model showed that at particular times cave 13F and others would have been sealed by a paleo-sand dune, thus making them inaccessible and potentially uninhabitable to early *Homo sapiens*.

Furthermore, on a more regional scale, modeling the presumed location of sand dunes around 180,000 years ago provides testable evidence on the location of archaeological deposits (Figure 3). With some lower caves partially filling in by paleo-dunes, other caves (located higher up along the cliffs) would, presumably, have been occupied. This is argued to be the case as archaeological deposits were found in caves currently accessible only with climbing gear. Extending the multidimensional GIS model to a regional scale would be an effective way to organize potential survey.

Sea level and other landscape modeling is important for understanding the paleo-landscape because landscape use patterns is a part of early *Homo sapiens*' marine foraging – thus significant to hunter-gatherer economy. The relative sea levels would impact marine resources in the immediate vicinity and, conversely, mobility patterns for early *Homo sapiens.*

Conclusion
Based on the success of the multidimensional model created for cave 13F, other models will be created to extend to sites within the cave series and the overall landscape of the immediate Mossel Bay region. In turn, archaeologists have come away with a GIS model that gives not only cave morphology, but also the environmental context of Middle Stone Age archaeological deposits within the area.

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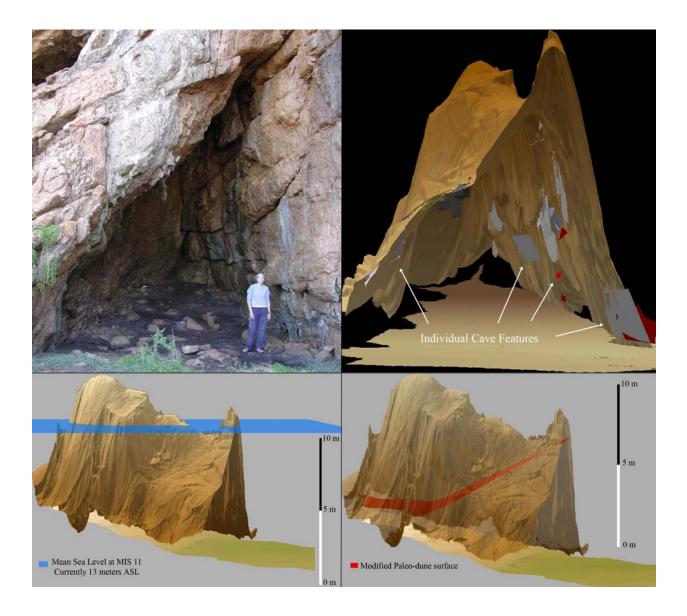
Figure 1 The Upper Left image is a photograph of Cave 13F as it appears in real life. The Upper Right image is Cave 13F as it is modeled in the 3D GIS including polygons representing individual cave features. The Lower Left image shows Cave 13F in relation to sea levels during MIS 11. The Lower Right image shows the modeled infilling of Cave 13F by sand during MIS 6 and MIS 5d-4.

Figure 2 The top image shows what the mean sea level during MIS 5e would have looked like in relation to current topography and the positions of Cave 13B and Cave 13F (submerged). The bottom image is a top-down view of the same model showing the semi-transparent MIS 5e sea level overlaid on top of a georeferenced image of the current sea level. Cave 13B is represented in red.
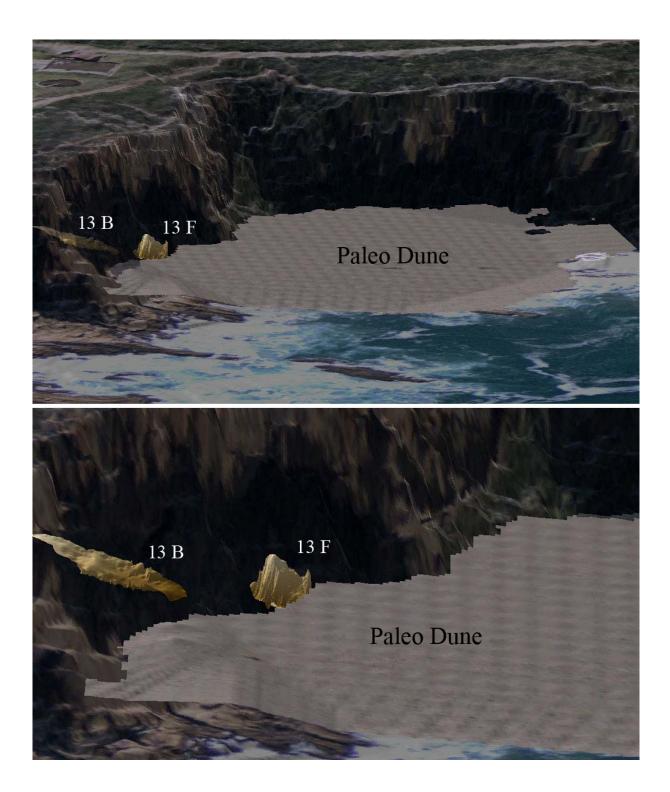
Figure 3 The top image shows a low-oblique view of Pinnacle Point, Mossel Bay and the model of a paleo-sand dune which existed in the area around 180,000 BP. The bottom image is the same model focusing on the relation between the modeled sand dune and the positions of Cave 13B and Cave 13F.