Merging Technologies: The integration and visualisation of spatial data sets used in the project

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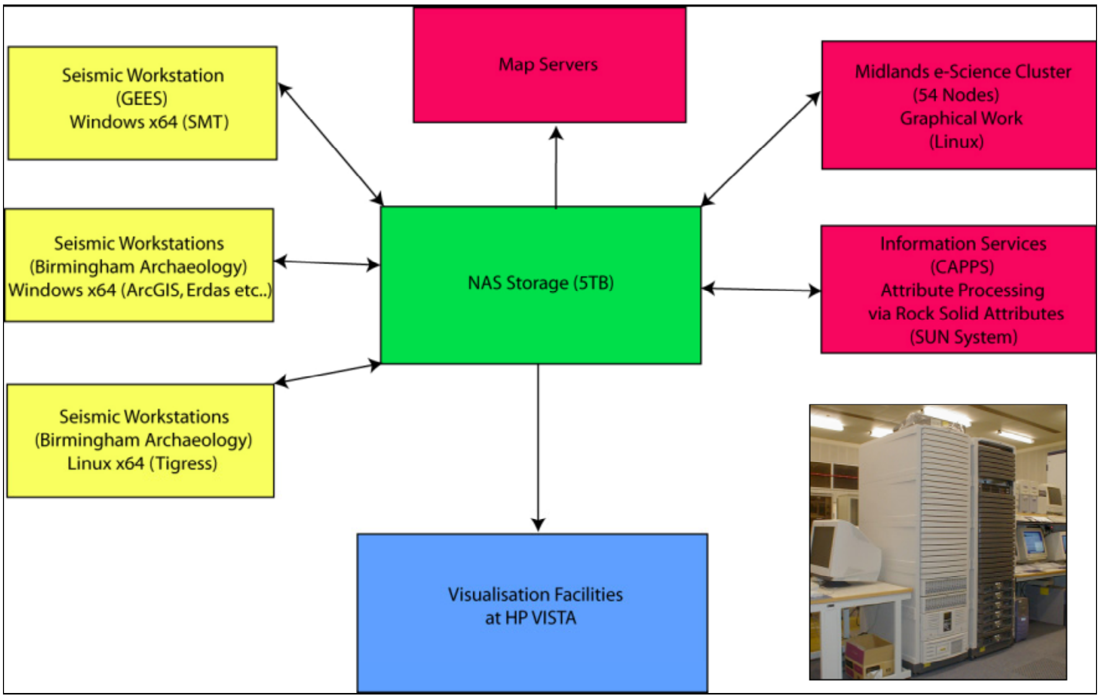
Abstract
The datasets utilised by the North Sea Palaeolandscapes Project are amongst the largest ever utilised for archaeological purposes. their analysis has been a technical challenge This paper provides and overview of the technology and infrastructure required to carry out analysis and outlines the issues that were faced to integrate and display disparate 2, 2.5 and 3D data sources with the technologies available.

Keywords: GIS, Visualisation, Visual and Spatial Technology Centre

Introduction
The North Sea Palaeolandscapes Project's (NSPP) primary goal was to explore the Late Quaternary and Holocene Landscapes of the Southern North Sea through the use of c.23,000km^2 of contiguous 3D seismic data provided by PGS UK (www.PGS.com). Processing this large volume of data required considerable investment in both hardware and software . In line with most archaeological projects utilising large amounts of digital, remote sensed data there was a requirement to utilise both specialist softwares for the processing of primary seismic datasets and standard geographic information systems to manage, manipulate and display supporting data sets and interpretative layers (Gaffney and Gater, 2003 chapter 5; Chapman 2006). What is, perhaps, less usual within archaeology has been the requirement to provide access to high bandwidth networks and storage to cope with the major volumetric datasets used by the project and to provide access to high-end stereo-projection systems to visualise and to quality check the data as it was processed and interpreted. The management of the project through the HP Visual and Spatial Technology Centre (HP VISTA,) a division of Birmingham Archaeology, provided the technical capacity to support the project. Given the tale nature of the project and its significant technical demands some description of the technical context of the project is required

Infrastructure
The primary engines for the majority of analysis were three HP xw8200 workstations with 64bit dual processors, 16Gb of RAM, 2Tb of local storage and high end graphics cards. The majority of primary processing was carried out on these machines although specialist software, used, for instance, to carry out attribute analysis of the seismic data, were resident on a machines elsewhere in the campus. Project data was held centrally on a secure 5Tb NAS storage system resident within the University Information Services' machine room. The need to move data between these machines and to the central storage was supported by gigabit enabled cabling between most project computers, and assisted by the availability of a dedicated fibre optic link between the NAS and the main display centre in the HP VISTA centre. The extent and complexity of the volumetric data and the utilisation of solid modelling and opacity rendering techniques required that the data could be viewed stereoscopically and also that displays were large enough to provide the opportunity of group viewing to discuss interpretation as a team. This was provided through the VISTA centre at Birmingham via an HP's SV7 scalable visualisation system. This is a multi-pipe

system providing high-end, high quality visualisation. A particular benefit of the system is enabling the selection of the level of performance, image quality and resolution independently, so a large model can be rapidly manipulated at a lower quality/higher performance level and then a particular region of interest examined at a high quality/lower performance level without having to interrupt the visualisation. The SV7 supported projection across a 4.27m by 1.8m dual channel rear projection Fakespace PowerWall which provided geometrically accurate stereoscopic display using active stereo glasses. This combination of analytical power and sophistication of display, whilst rare within archaeological projects, was demanded by the nature of the datasets under investigation and is comparable with specialist facilities dealing directly with petroleum geology, remote sensed, data sets. It is, perhaps, worth noting the scale of change represented by the NSPP's computing requirements and the exponentially increased use of digital data within the NSPP. To put this in context, a paper published 10 years ago, also on the issues of integrating GIS and other spatial technologies within archaeological projects at Birmingham, records the fact that at time the entire archaeological computing group, which was also carying out landscape-level remote sensing projects, was then serviced by a server with 64 megabytes of RAM and 4 gigabytes of mass storage (Buteux et al. 1997, Gaffney and Gaffney 2000).



Software integration

Having established the infrastructure requisite to implement the project it is appropriate to consider the requirement for software integration that arose during the course of the study. The increasing application of geographic information systems to manage, manipulate and display spatially referenced data set within archaeology, and related disciplines, has been a major trend over the past decade.(Chapman 2006, Connoly and Lake 2006). Not surprisingly, the majority of the NSPP's interpretative and supporting spatial data has been held within an ARCGIS database which has been available to all team members. A similar trend in the use of technology is discernable within other groups dealing with hydrocarbon exploration where the ability of GIS technology to handle a variety of spatial data, in conjunction with its analytical capacity, make GIS an invaluable tool for Petroleum exploration (Gaddy 2003). Further, the ability of a GIS to visualise and manage data throughout a projects life has proved invaluable to the petroleum industry in recent times (c.f Lawley and Booth, 2004).

Despite this promising situation, the scale of data use and the incorporation of non-traditional digital data sources proved problematic during the course of the NSPP. Issues primarily related to the volumetric nature of the data used and the size of the datasets themselves. It is notable that the use of GIS within the petroleum industry has run in parallel with the development of 3D modelling systems, alongside remote sensing packages, that link interpretive and geophysical data (Gaddy 2003, 1). Software's such as Tigress and SMT Kingdom, able to image vast, complex geophysical datasets, facilitate the mapping, management and planning of petroleum data within an easily visualised environment. The requirements of the petroleum industry have produced highly flexible interpretation packages and industry requirements are very similar to those of the NSPP (see Thomson this Volume) and the utilisation of these well developed and reliable packages was therefore highly desirable and applicable to the archaeological analysis required by the project.

Within Marine archaeology, the use of GIS to assist in archaeological management is fundamental (Groom and Oxley 2001, 56). Distributional analysis of marine and associated resources, or even analysis of absence of evidence, permits targeted use of resources in curatorial terms and provides a greater insight into the structure of the marine database (Groom and Oxley 2001; Allen and Gardiner 2000, Fitch et al. 2005, 194). The utilisation of geophysical information in this role within a GIS is also well understood within the archaeological computing community (e.g. Buteux et al. 2000, Gaffney et al. 2000). This has proved invaluable when monitoring landscapes that contain poorly understood archaeological resources (Chapman et al. 2001). In projects, such as the NSPP, where archaeological survey and interpretation severely limited by the prevailing physical environment, the ability to combine data sources including geophysics, physical samples and findspots to provide a proxy environment for interpretation is crucial.

The use of GIS to explicitly integrate traditional land based geophysical surveys (e.g. Magnetometry and Resistivity) as well as remotely sensed imagery is also reasonably well established (Gaffney et al. 2000). The planar nature of these traditional land based geophysical surveys facilitates their easy integration into a traditional GIS's map style interface. However the representation of a true three dimensional volume data, including 3D seismics, is a challenge to systems that are, essentially, 2D. (Kvamme 2006, Watters 2006, 285).

Whilst the representation of a third dimension is possible within certain GIS viewers, such applications are not ideal for the purposes of representing volumetric geophysical data, as these do not allow for the representation of voxels. Such systems are therefore unable to adequately display a volumetric representation of a cube of seismic 3D data. Within the NSPP there was,. therefore, always a requirement to explore the means by which volume data could be integrated with standard GIS map layers in a manner that retained some integrity of the original volumetric data

Primary integration procedures

Whilst proprietary tools do exist to allow the display the products of analysis of seismic data within a GIS, this has generally been achieved through the rectification of a flat image from which interpretation can be undertaken. With respect to seismic surveys, integration of a cube of data can be achieved thought the export of serial planar, timeslices. This facilitates interpretation alongside more traditional GIS layers in a traditional fashion (Goodman and Nishimura. 2000). However for the Southern North Sea project it would be undesirable to introduce all the possible time slices within the GIS. Indeed, to display the number of seismic attributes used in this project would result in tens of thousands of slices and data layers. This would add unnecessary complexity and vastly increase the amount of data to be manipulated. Indeed, management of such a volume of data would probably beyond the capacity of most GISs and, probably, impossible for a human operator (Kvamme 2006).

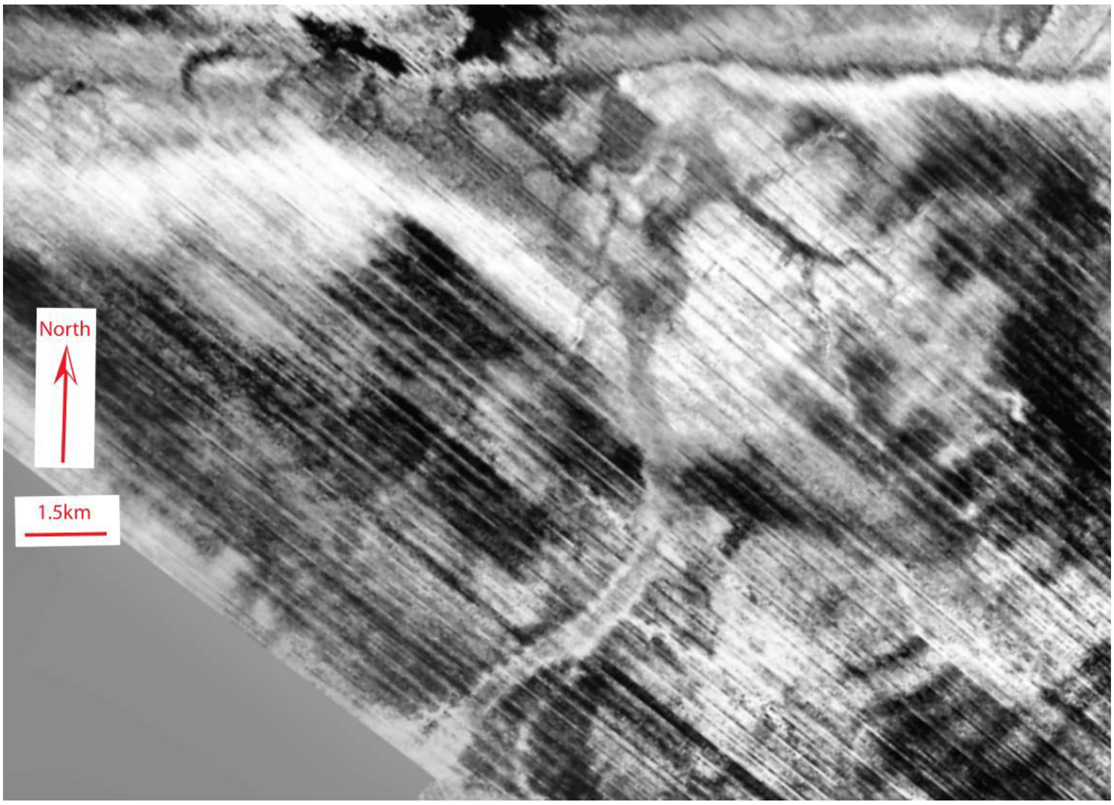


Figure 1 - Seismic data slicer showing fluvial channel and estuary

Consequently, in the first instance a selection of slices from the most commonly used data attribute amplitudes were selected to provide an overview of the dataset. This selection, however, does leave open the possibility that significant information may be missed between slices. To compensate for this the NSPP utilised RMS amplitude slice technology (root mean squared, see Thomson this volume) to facilitate the display of some of the information within the missing volume within a standard 2D image. The resultant slice therefore shows areas of anomalous seismic amplitudes within the selected volume, and can be useful in imaging channels (see figure 1). The resultant output is a planar slice, admirably suited for the integration into a standard GIS system, and satisfies some of the requirements of Kvamme (2006) for displaying this style of information. Further the nature of its generation means that it is highly accurate in terms of spatial location, and is only limited by the properties of the originating seismic survey. Thus such an approach is ideally suited to the interpretation and representation methods that have been relatively standard in archaeological prospection (see Watters 2006 for a comparable process used to process GPR data).

Integration of volumetric nnformation through solid modelling

Whilst RMS slice technology does allow for the display of some of the information contained within the volume of seismic data, its generation as a planar slice results in the loss of integrity of complex structures because the three dimensional component of any anomaly is not adequately represented. The potential to lose significant data is therefore very real. From the outset of the project it was decided to follow common practise amongst petroleum geology groups and to use the sophisticated display technologies available at Birmingham to implement analyses permitting solid modelling and full 3D and stereo visualisation to maximise information extraction.

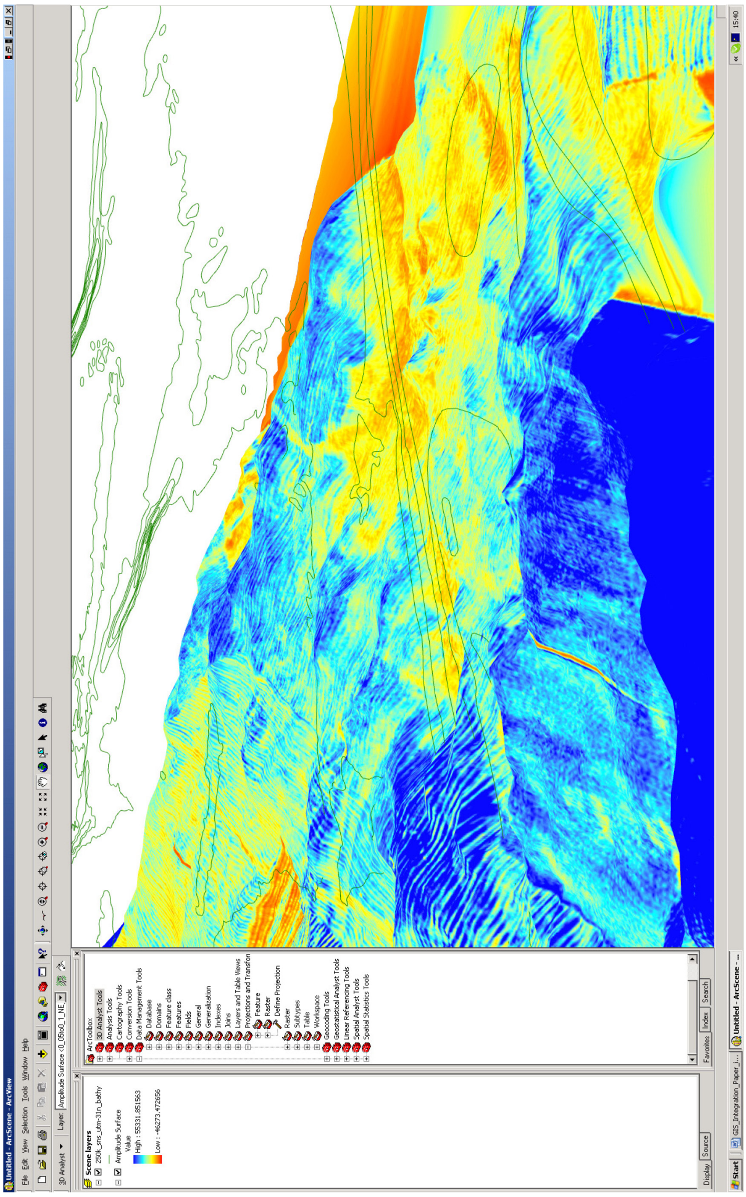


Figure - 2 - 3D amplitude surface within a GIS. The green linear lines are bathymetric contours, and allow for the visual correlation between the anomalies and seabed topography.

3D surface modelling has been utilised within archaeological geophysics for some time (e.g. Neubauer & Eder-Hinterleitner 1997). Yet fundamentally these still represent only a single layer or, at best, are 2.5 dimensional in nature. They are not therefore suitable for the representation of the volumetric 3D seismic data or for the exploration of internal structure in complex volume features.

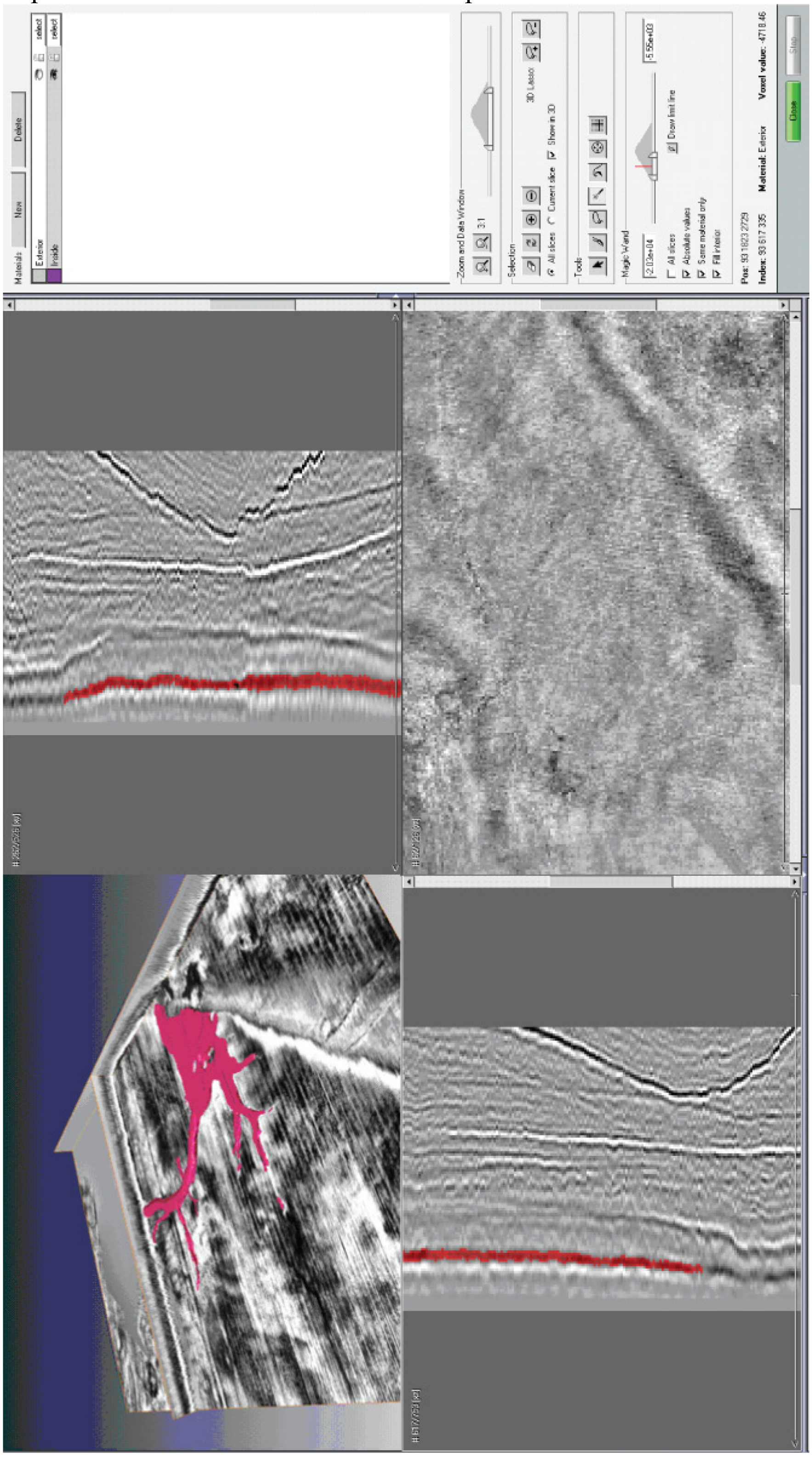


Figure 3 - Segmentation of features of interest from the seismic volume.

Mercury Software's 'Amira' visualisation package was utilised within the NSPP to provide a visual insight into the volumetric components of anomalies observed within the 3D seismic data. This was supplemented by purchase of the Amira "Very Large Data Pack" which supports datasets that may be hundreds of gigabytes in size. . Representation of anomalies from industry standard SEG-Y data is possible utilising the recent developments in Amira software. These were developed to facilitate geological visualisation services for the oil and gas industry. Following import, Amira possesses a suite of tools which make it an effective environment to explore, analyse and display many types of remotely sensed data. The ability to specifically extract information contained within voxels through a series of solid models using this software has recently been demonstrated by Watters (2006).

To achieve the required volumetric models, the original seismic data was directly segmented utilising picking techniques that are commonly employed in the oil and gas sector (figure 3). Through the segmentation of features of interest, a series of user determined lists are generated which contain features of interest,. Fully automated selection tools can be utilised to define the voxels contained within each feature. Although this can be an automated process boundaries noise at survey boundaries and within the top of the data column prevented such a simple implementation. Consequently, it was necessary to utilise a semi-automatic process of isosurfacing, utilising user set boundaries and thresholds to constrain the process of automatic voxel identification. With the required information extracted from the seismic dataset, a solid model was built for each feature using the segmented data by generating a three dimensional frame to each feature model (fig 4a+b). Once constructed, it is possible to disassemble a features structure through slicing to gain further insights into the three-dimensional structure (see figure 5). Further information can also be gained through volumetric analysis within the solid modelling package. For example the determination of average Volex value within a volume according to assigned values or attributes may have particular significance. The calculation of channel volume is an obvious output from such a model. However, whilst valuable in their own right such modelling packages are constrained in analytical terms as they lack the majority of spatial procedures available to the majority of GIS's.

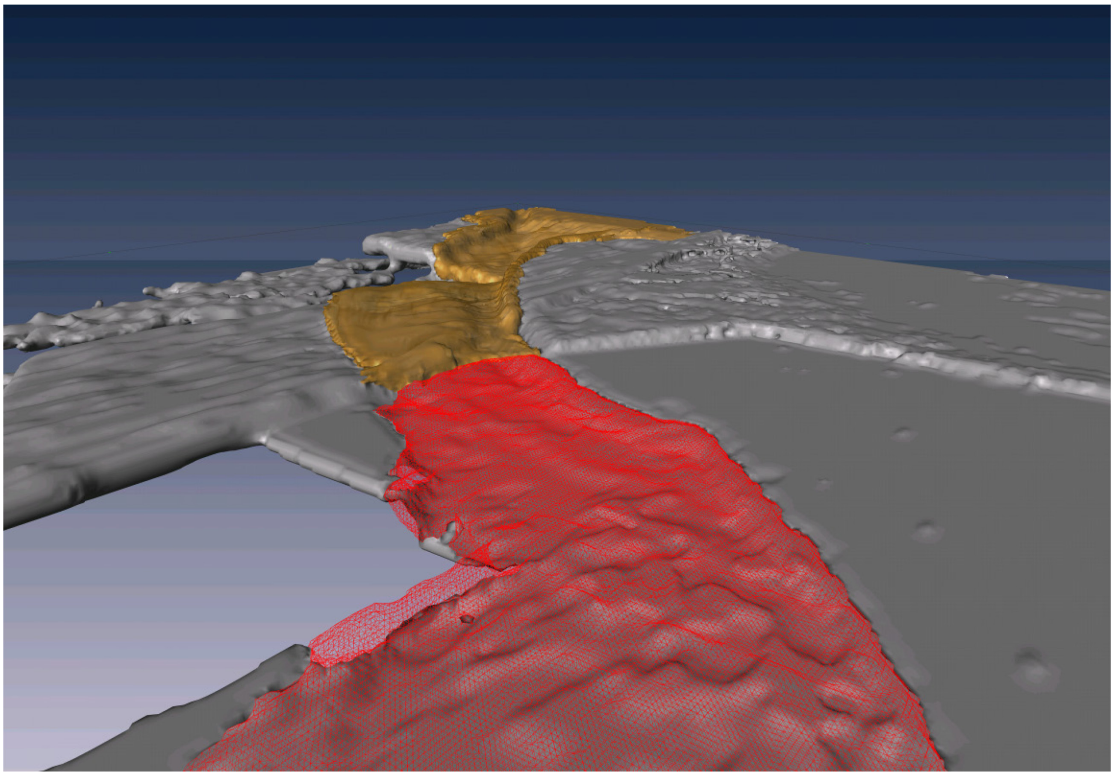


Figure 4a - Wrapping of identified features within the Seismic data

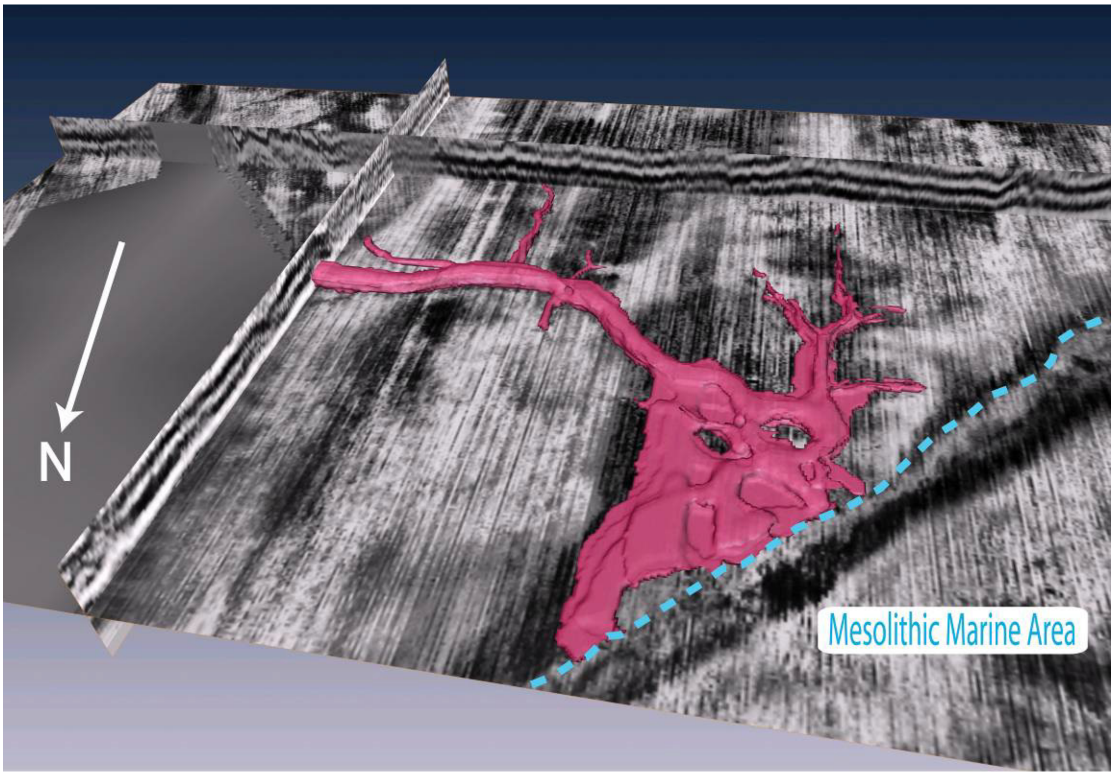


Figure 4b The resultant solid model generated by wrapping

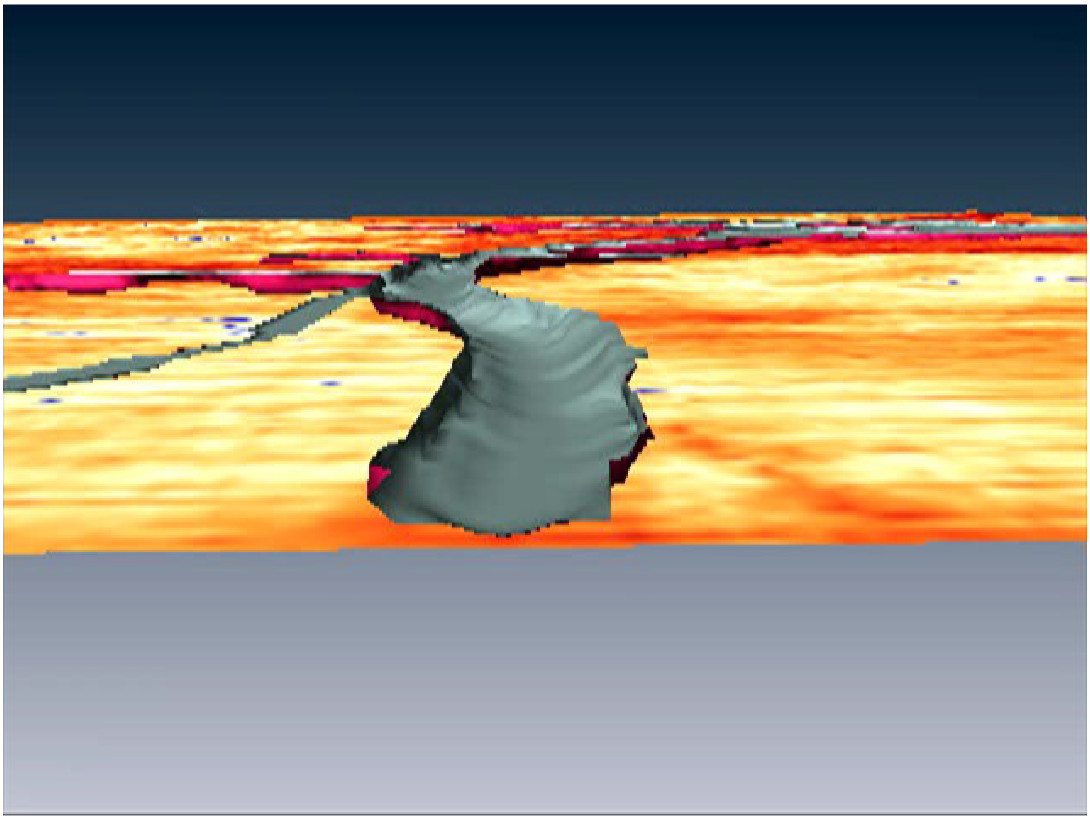


Figure 5 - Illustrates the removal of elements of the Solid model within the Amira package from figure 4b to allow a visualisation of the internal structure of the system.

As the volumes forming the solid model represent have real world attributes in all three dimensions, it becomes possible to generate suitable CAD models that can be imported into GIS visualisation tools for display, as well as spatial analysis. This mode of representation is more suited to GIS display, since it is composed of polygonal elements which, as they wrap the entire anomaly, can to allow the user to appreciate and visualise the actual volume and size of anomalies. The results of part of such work can be seen in figure 6. However the process of export of these models from a fully three dimensional environment into a GIS, whilst allowing a representation of the shape and size of the anomalies, fails to represent the attributes of the anomaly and the volume of the originating survey. Although it is possible to transfer attribute data to GIS data layers, solid modelling remains a superior method to represent anomalies contained within volumetric geophysical data rather than standard planar slice.

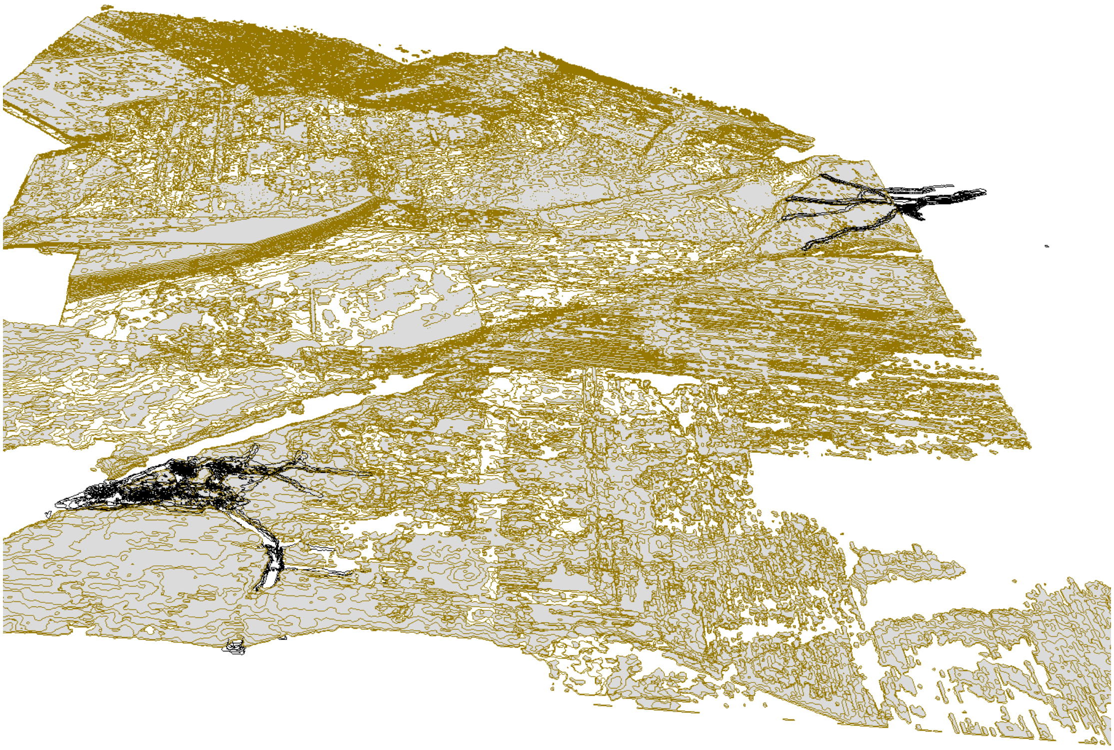


Figure 6 - Exported Solid Models within the GIS system. Features in black are composed of contour models, whilst the large area is a large polygonal model of the landscape.

Merging technologies

Software groups have appreciated the increasing importance of GIS data and the requirement for integration with specialist data. 3D seismic interpretation packages including Tigress and SMT's Kingdom software have the ability to create and display datasets derived from, or exported to, a separate GIS. Consequently, GIS layers can be integrated within a fully 3D environment which provides the capacity of displaying not only the voxel volume of the dataset, but vector or polygon features derived from that data (figure 7). The ability to display associated GIS information, and the ability to produce GIS interpretation layers directly within the package helps reduce spatial positioning errors which may occur during traditional planar slice integration. The direct generation of GIS-compatible interpretative layers within specialist packages also improves quality of the interpretation through the availability of advanced attribute and opacity rending techniques not available within a standard GIS (see Thomson this volume).

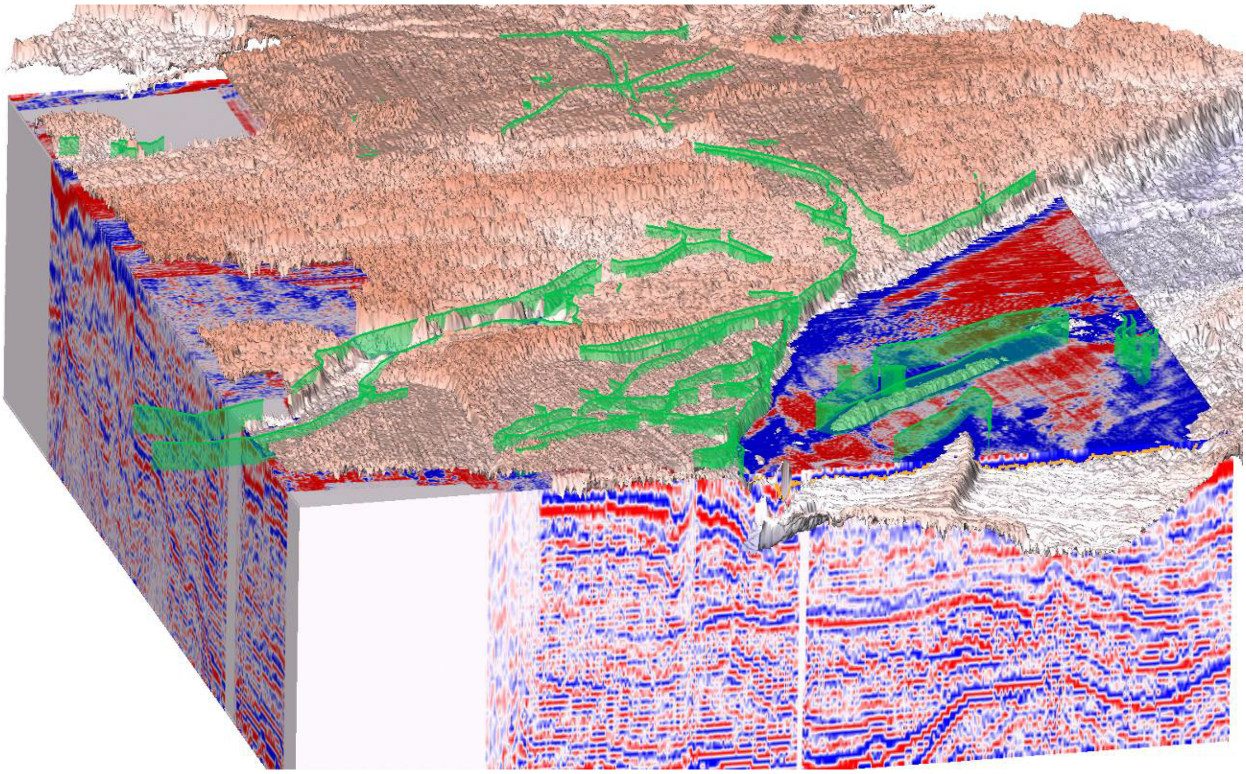


Figure 7 - GIS Layers display within a fully 3 Dimensional environment - Cube of Siesmic data - displayed as Voxel Volume - 3D surface & 3D GIS polygons (interpretaion layer).

Conclusion

It is apparent that the utilisation of solid modelling packages to provide seismic volumetric data can assist in integrating complex 3D data within a GIS. However, it must still be acknowledged that the process of exporting data divorces the solid model from the original volumetric datasets and, potentially, important attribute data or specialist attribute derivatives. In the end, this must limit the analytical potential of derived data. However, integration within a GIS also provides enhanced opportunities for spatial analysis plus integration with other, supporting spatial datasets and this cannot be achieved adequately within any proprietary seismic processing package. Until the technologies merge further, and this is a real trend in software development, linking technologies, including solid modelling, offer the best way forward for the integration and visualisation of information derived from both geophysical survey and GIS.

Finally, it is acknowledged that the integration of all data sources utilised by archaeological, or related projects, is probably not feasible and, perhaps, may not even be required at this point in time. However, what is incontrovertible is that the complexity of our analyses demands that we are able to transfer the rich spatial data that we use between technologies that permit us to visualise them in an appropriate, and increasingly sophisticated manner. Indeed, this may ultimately be the most significant point. Our ability to visualise data is increasingly a primary driver and is linked directly into novel interpretative positions With 3D data sets, in particular, it is our capacity to facilitate visualisation, through linkage between diverse softwares, that allow us to view data in a variety of exciting manners. Within the larger context of available spatial data sources, ut is this that will enhance our interpretation of novel data sets and, ultimately, our understanding of past landscapes.

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