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3D MODELLING OF THE CALLABONNA SUB-BASIN (SOUTHERN CURNAMONA REGION)

Luisa Ruperto and Malcolm Nicoll

CRC LEME OPEN FILE REPORT 184

June 2007

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Headquarters: CRC LEME c/o CSIRO Exploration and Mining, PO Box 1130, Bentley WA 6102, Australia

This report describes the data and methodology used in the 3D Model of the Callabonna Sub-basin (southern Curnamona Region), with specific focus on the use of Gocad (3D modelling software) as a central component of the modelling process. It also serves as a supplement to the LEME Open File Report 183 “Geological Review of the Southern Curnamona Region” 2006 by Ruperto and de Caritat.

Copies of this publication can be obtained from:

The Publications Officer, CRC LEME, c/- CSIRO Exploration & Mining, PO Box 1130, Bentley WA 6102, Australia. Information on other publications in this series may be obtained from the above, or from <http://crcleme.org.au>

Cataloguing-in-Publication:

Ruperto, L.

3D Modelling of the Callabonna Sub-basin (southern Curnamona Region)

ISBN 1 921 03919 1

1. 3D modelling

2. Regolith

3. Gocad

4. granulometries

Ruperto, L.

CRC LEME Open File Report 184

ISSN 1329-4768

Addresses and affiliations of authors

Luisa Ruperto

Cooperative Research Centre for Landscape
Environments and Mineral Exploration
c/- Geoscience Australia
GPO Box 378
Canberra ACT 2601
Australia

Malcolm Nicoll

Predictive Mineral Discovery
Cooperative Research Centre
c/- Geoscience Australia
GPO Box 378
Canberra ACT 2601
Australia

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ABSTRACT

The aim of this project was to construct a 3D stratigraphic model of the Southern Callabonna Sub-basin using established grain size classes (granulometries) and incorporating data from 827 drillholes collected over the area in 1997 by Matthew Killick. This report describes the data and workflow used in the study with a specific focus on the application of Gocad (3D modelling software) as a central component of the modelling process. This report also serves as a supplement to the LEME Open File Report 183 'Geological Review of the Southern Curnamona Region (2006) by Ruperto and de Caritat. Methods used here are only an example of the tools available to 3D modellers and it must be noted the model outputs are wholly dependent on the quality of the input data. Ideal outcomes include a detailed understanding of regolith thickness, architecture and hydrogeological/hydrogeochemical processes in this important area of exploration interest.

INTRODUCTION

Groundwater has been identified as a useful medium for highlighting transported chemical and isotopic constituents that can be used to derive a chemical footprint for potentially economic sulphide mineralisation (Caritat et al., 2005; Caritat and Kirste, 2005; Gray, 2001). This is especially true in areas obscured by cover. Few published attempts (Caritat. et al., 2000) have been made to model the spatial distribution of transported sediment (such as sand, clays, etc) in 3D throughout the Curnamona region of the Southern Callabonna Craton in South Australia. This report describes the methodology used in attempting to model the Curnamona's sub-surface regolith structure in 3D, highlighting regions of aquifers and aquitards and therefore identifying possible vectors for mineral transport through cover. It is this 3D model that is being used as the basis for a 4D hydrogeological model which will help to identify and constrain groundwater flow regimes within this upper sedimentary unit of the Southern Curnamona Province.

Log data from 827 drillholes collected from surface regolith, subsurface sediment and saprolite samples (Appendix A) formed the base dataset for this study. Previous studies of this dataset carried out by Killick in 1997, describe the outcomes of a number of isosurface volume models that coarsely modelled the spatial distribution of sediment patterns as interpreted from the drillhole logs which were classified into five sediment classes (Gravels, Sands, Clays, Silts and Other)(Caritat et al., 2000). This resulted in a 3D interpretation of the palaeotopography, structural framework and depositional style of Cainozoic sequences within the southern Curnamona Craton. It is this previous work which is being re-visited as the basis for this project for the purpose of refining the model and increasing the confidence of the patterns displayed.

Accompanying this technical document is a literature review (OFR 183 "Geological Review of the Southern Curnamona Region" Ruperto and De Caritat, 2006) that was used to constrain the model building process. It ensured the modelled surfaces honoured the literature and were true to the environment we were modelling. For example, industry reports provided accounts of deposit host rock stratigraphy within the palaeovalley regions of Yarramba (Honeymoon Mine) and the Beverley Mine near the Flinders Ranges in South Australia. While groundwater data collected by CRC LEME for the Western NSW Geochemical GIS (2003-04) was also used as another constraint to ensure an accurate sedimentary context was preserved.

METHODS

Data Processing

The original dataset was compiled in such a manner that it was difficult to interpret given the lack of available documentation for this study. It was therefore decided to generate our own classification system that would make sense to the scientists involved in the project and that would be easier to manage. The first task was to calculate percentage granulometries for each drillhole log, thus allowing

the reader to make a quick assessment of the downhole sedimentologies. A simple numeric classification was devised based on a ternary diagram (Figure 1) where each granulometric percentage was categorised in terms of a numbered colour scheme with each colour denoting a specific sediment type. For instance, a granulometric sample classified as 100% gravel/sand registered a colour value of 2 (red) as described in Table 1.

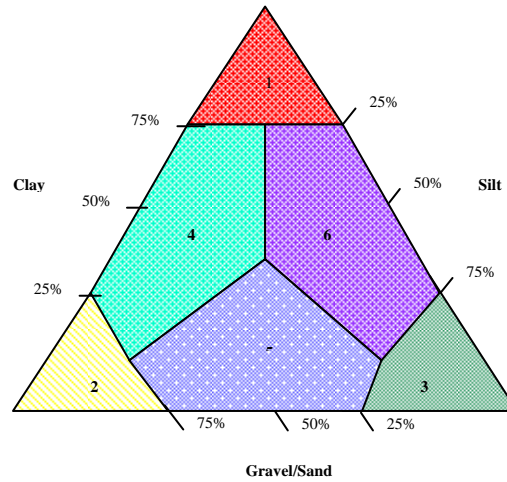


Figure 1. This tri-plot diagram allocates a representative value/number for each possible sediment class combination. For instance, a log record with 20% gravel-sand, 70% clay, 10% silt would be allocated a value of 4.

Number Allocated	Granulometric Fraction	Colour Assigned
1	>75% Clay	Red
2	>75% Gravel/Sand	Yellow
3	>75% Silt	Green
4	Clayey-Sand	Cyan
5	Silty-Sand	Blue
6	Silty-Clay	Blue violet
7	>50% Other	Magenta
8	<50% Other	White

Table 1. Colour schema used in classifying granulometric fractions based on colours and numbers in Figure 1.

Additional drillhole data were accessed from PIRSA’s online digital drillhole database (SARIG) and were introduced into the study to enhance the integrity of the original dataset. It was a common occurrence to find a PIRSA drillhole situated between two of Killick’s data points enabling us to use this extra data to ‘fill in the gaps’ between known points.

A variety of software packages were used for this project that include MS Excel, ArcGIS/ArcMap (ESRI), and Gocad (Earth Decision Sciences). ArcMap was used for display purposes and to ensure that drillholes were plotted in the correct geographic location within Gocad. ArcMap proved to be particularly useful for accurate and rapid querying of drillholes in the 2D space relative to 3D, where there were significant difficulties in correctly distinguishing the properties of a unique hole from a

whole field of similarly displayed points in the Z-plane. It was often required to re-work the data files in terms of their structures/formats so as to facilitate reading/importing into the 3D modelling package, Gocad. For example, Excel and custom programs using GAWK (Appendix B) scripts were used to convert the well data files into various formats such as curves and points each to aid a different modelling purpose.

Modelling

The complex task of generating a 3D model using Gocad is a multi-step process. For this Curnamona model, the majority of objects including wells, vectors, surfaces and volumes (described below) were generated from the single amended set of drillhole data.

All drillhole information was converted to Gocad's native 'Well Object' format using custom GAWK scripts (Appendix B). Each file format consists of a header and log section for each "Hole" (Appendix C). The header section contains a unique identifier for each entity (e.g. a drillhole id, or a well name). It also consists of a 'path' (collar position in xyz co-ordinate planes and 3D geometry of the hole), a 'marker' which identifies any significant features at depth along the drillhole log. In this case, the marker stores the top of the "weathered rock" surface. The 'zone' stores the facies classification and the differing depths at which these occur. The log section of a well object contains property data that has been sampled along the path, specifically, percentage granulometries for the four different facies types.

The drillhole data was processed in a number of ways to aid various purposes; firstly each drillhole was visualised as a Gocad well object (Figure 2). The well logs depict the relative granulometries for the downhole depth range. This allows a visual analysis of grain size trends and to carry out quality control on the data. The drillholes were converted to curve objects resembling 'sticks' in an effort to increase rendering speed (Figure 3). These curves are classified based on facies type and are colour coded according to the ternary diagram in Figure 1, thus permitting rapid visualisation of gross spatial patterns. The facies data were then re-sampled and converted to a Gocad 'point' object (Figure 4) which was used to constrain the facies property in the Gocad 'voxet' object (described in a later section). The resample rate was adjusted to suit the cell spacing of the voxet, the aim being to provide at least one constraint per cell.

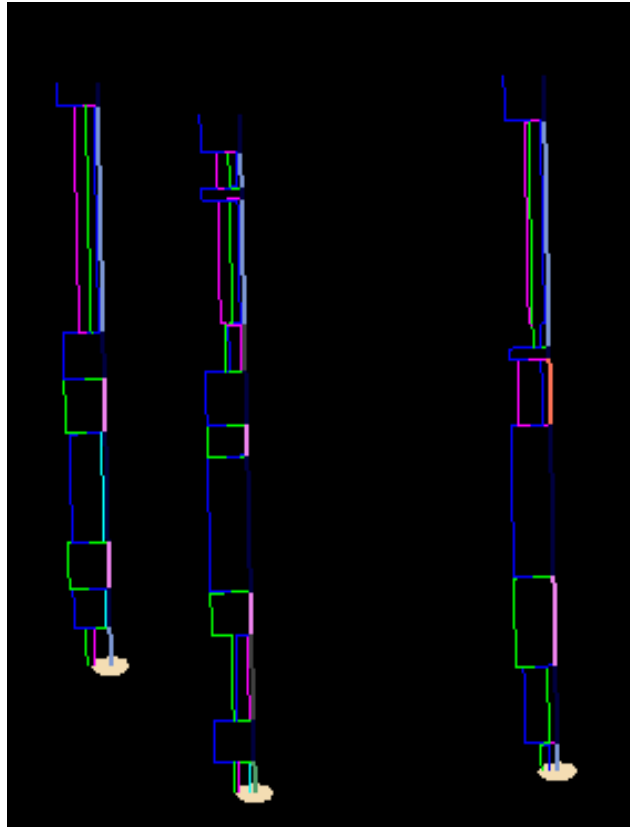


Figure 2. Downhole drill data is displayed as a well log. The varying colours indicate the different facies types and dominance for each depth range (in the lateral direction). The beige disc represents the depth at which Cretaceous sediments are intercepted and thus representative of the top of the Callabonna Sub-basin.

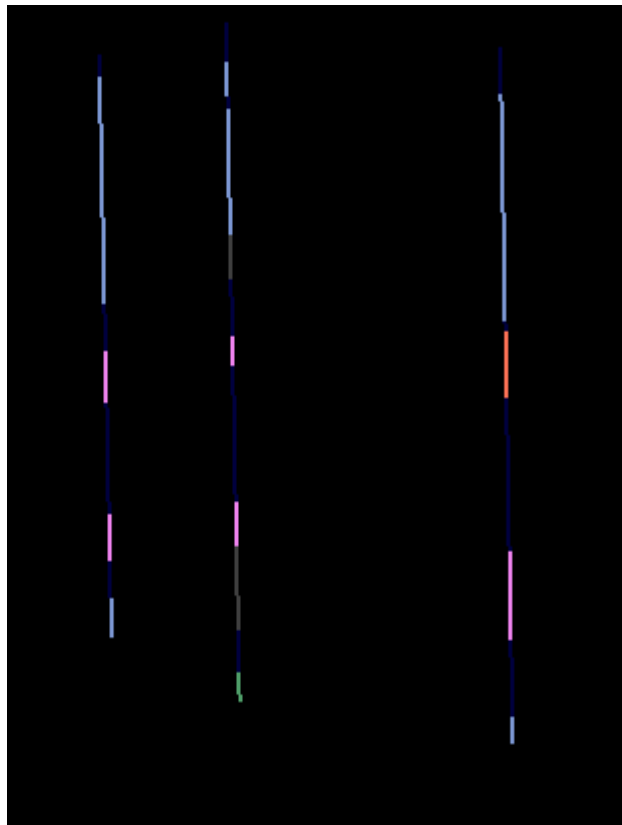


Figure 3. Wells (in curve form) enables for faster rendering and visualisation of spatial patterns.

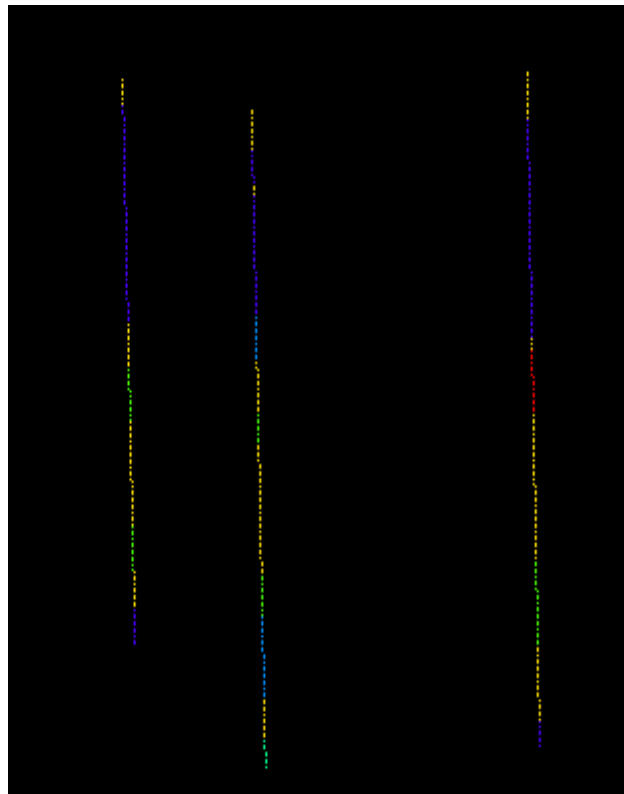


Figure 4. Facies classification resampled into 'point' data type. This is used to constrain the properties for volume interpolation.

Three surfaces were constructed in this project (Digital Elevation Model [DEM] representing the topographic surface, the top of the Willyama basement and the top of the weathered rock ie. the top of the Callabonna). A subset of the national 9sec DEM was converted into an XYZ file using ER Mapper before being imported into Gocad as a point data set or 'pointset'. This Pointset was used to constrain a coarse triangulated surface mesh which was then interpolated to fit to the data points using Gocad's in-built DSI (Discrete Smooth Interpolation) method (Mallet 1989). The triangle size of this mesh was then optimised by examining the constraint-to-surface errors and automatically densifying the mesh in high error areas. This process was repeated until an efficient surface that honoured the constraining data was produced. The resultant DEM surface (Figure 5) provided a spatial and visual context for the study area enabling spatial orientation within the landscape. One hundred times vertical exaggeration was applied to this surface for querying, surface interrogation and enhancing visual accessibility to layers. Such a large degree of exaggeration was necessary as the lateral extent of the study area was grossly disproportionate to the vertical extent and therefore required a substantial amount of enhancement to allow such small scale features to be seen with ease.

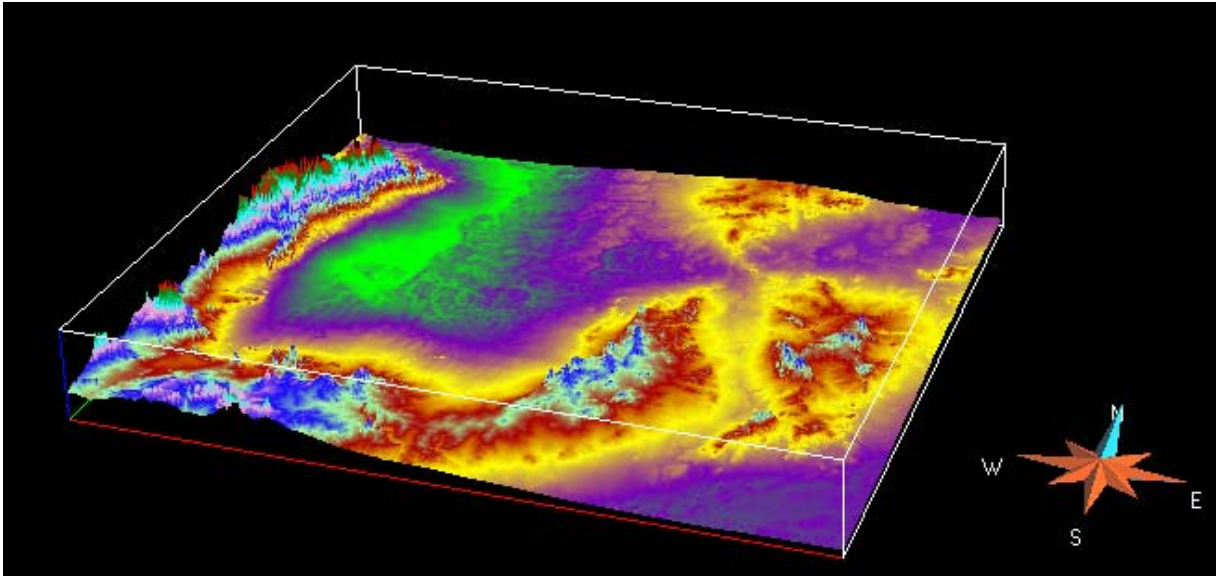


Figure 5. Clipped DEM of the southern Curnamona area formatted in XYZ style in Gocad displayed with a full 256 bit colour stretch. Vertical exaggeration (VE) of 100. Larger VE's are introduced to enhance small scale features and/or objects with a low scale range. Lake Frome is distinctive in the bright green topographic low adjacent to the exaggerated mountain range the Flinders Ranges. The Olary Ranges are located to the south.

The surfaces representing the top of the Palaeoproterozoic Willyama basement and the bottom of the Cainozoic Callabonna Sub-basin (Figure 6) were generated from well marker data within Killick's dataset. The maximum depth of the Callabonna Sub-basin unit is ~250m and represents what is termed 'transported sediment'. The basement surface (Figure 7) was interpolated from non-granulometric point data and seismic interpretation (PIRSA) which contained depth to basement information for holes within the study area. Due to the sparseness of the data DSI was again used to generate a smoothed surface that would provide a general physical structure of the Palaeoproterozoic basement geology in the area. As the model does not focus on units deeper than the Callabonna Sub-basin, it was not necessary for this basement layer to be as rigorously constrained to the same extent as the Cainozoic surface.

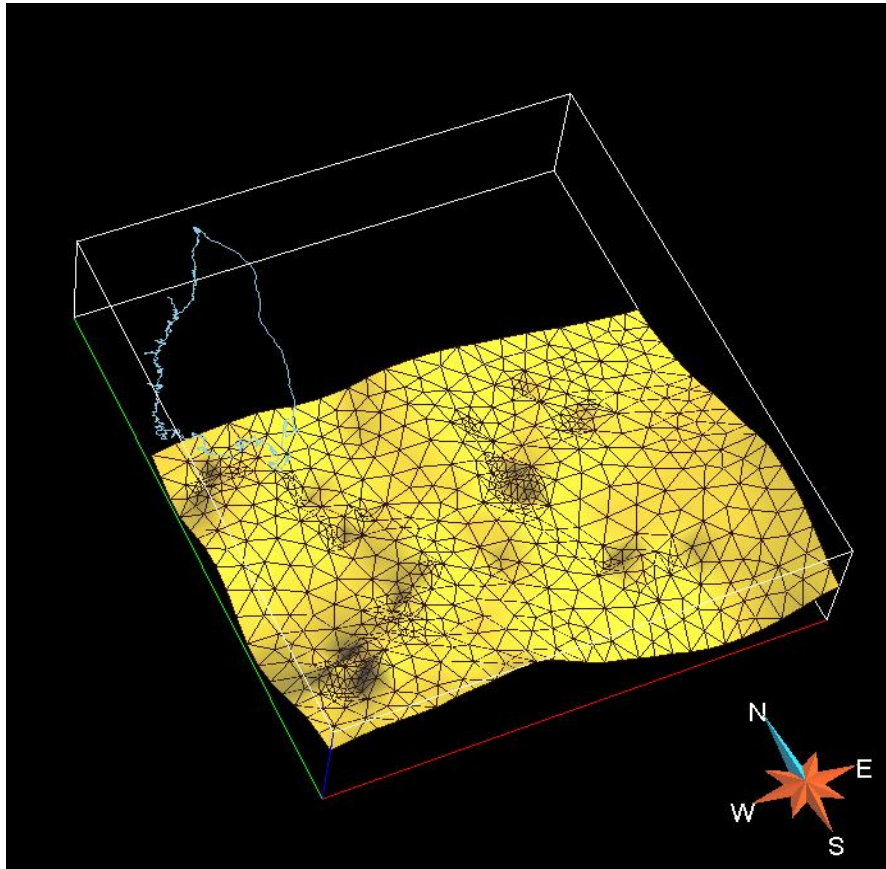


Figure 6. The fine black mesh is displayed on the base of the Callabonna Sub-basin surface. This demonstrates areas of higher triangle density in regions where more detail is required. VE=100.

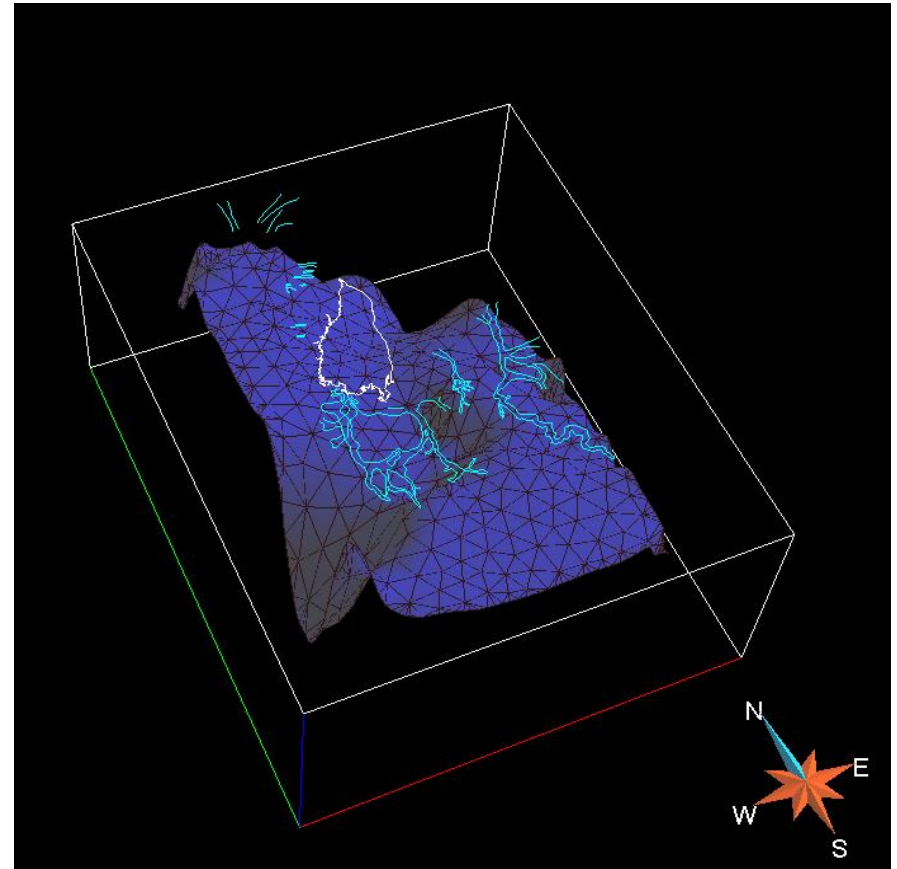


Figure 7. Palaeoproterozoic basement surface as generated from point data and seismic lines. Numerous DSI interpolative iterations were performed on this surface in order to honour the data as much as possible. VE=100.

The three surface objects (Figure 8) allow visualisation of the study area in 3D. The major stratigraphies are displayed as a stacked series with drillholes shown penetrating through the Callabonna Sub-basin (yellow surface) allowing the transparent nature of the modelled stratigraphic surfaces to be seen.

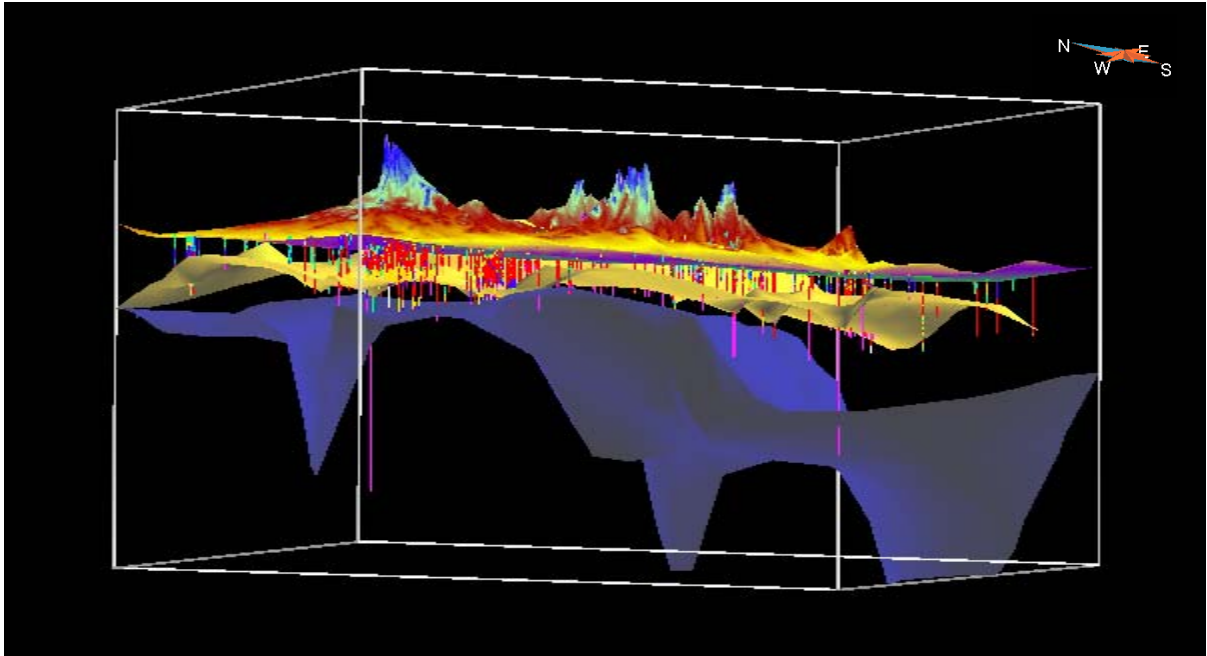


Figure 8. All three modelled surfaces illustrate the 3D nature of the model. The see-through effect is a valuable tool in demonstrating the inter-layering of surfaces and the interactions they play with one another. VE=50.

Vectors provide a useful tool for framing and delineating regions of importance. It is possible for vectors (Figure 7) to provide important attribute information on the spatial extent of a feature in an x-y plane. Shapefiles of Lake Frome and regional palaeochannels were draped over the digital elevation model and Callabonna surface to provide a visual perspective of spatial relationships in the area. Palaeochannel vectors proved to be a useful interpretive tool for identifying areas of potential aquifers as well as highlighting the position of incised channel paths, enabling inferences to be made of mineralisation areas within the sub-basin.

A Gocad voxet was built for the study area with a chosen cell size of 500x500x5 metres selected to reflect the anisotropic nature of the drillhole data. The DEM and ‘weathered rock’ surfaces were used to divide the voxet into three regions – Upper, Middle and Lower. Cells in the Middle region (representing the full depth of the Callabonna Sub-basin) (Figure 9) were constrained by the classified granulometry facies property from the drillhole data, followed by DSI to interpolate this property throughout the volume.

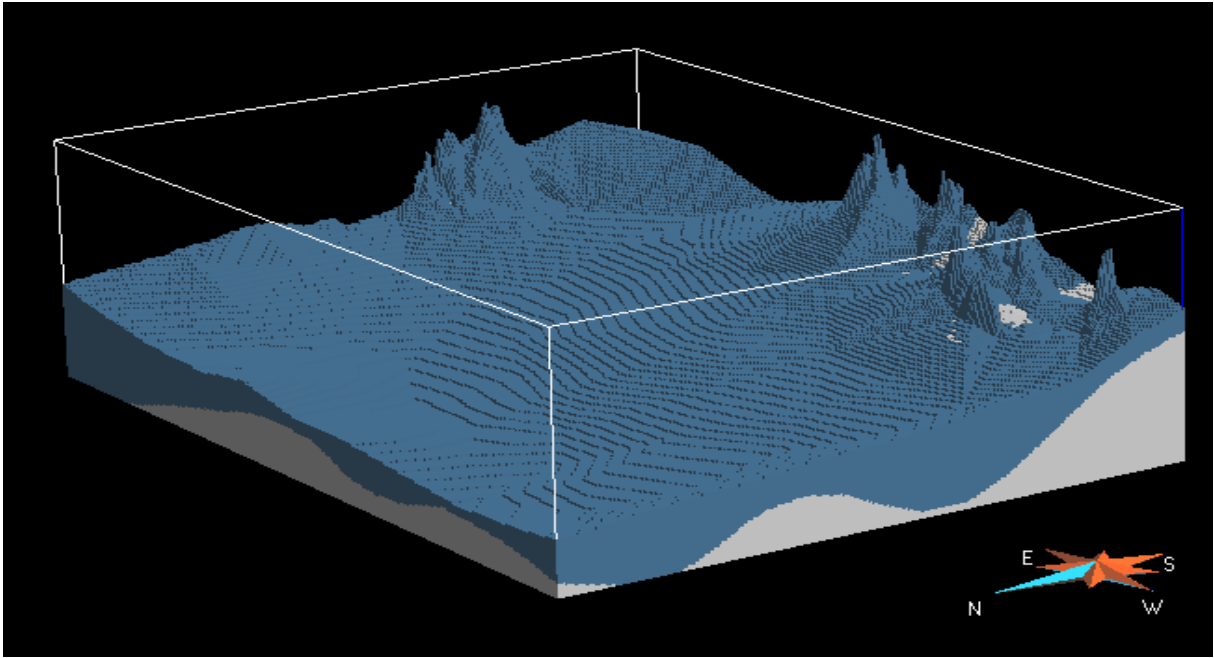


Figure 9. Solid representation of the Callabonna Sub-basin abutting the Willyama basement. All voxels (cubic cells in xyz plane) are filled with an interpolation of the surface data as propagated between the basement and weathered rock surfaces. This is a particularly useful tool in visualising a solid entity in 3D as opposed to a void in between two surfaces. VE=100.

From this solid volume, the facies properties identified in the original dataset are propagated through the Callabonna solid region, generating a facies voxel. The same colour ramp used to symbolise facies type is also employed here in the coloured slices of this volume. This slicing tool (Figure 10) allows for dynamic visualisation of the facies data as shown by moving the slicer in all directions. The viewer is able to identify areas within the voxel (for example) of high clay proportion and aquifer zones (gravel/sand bodies) in amongst the less porous sediments throughout the basin.

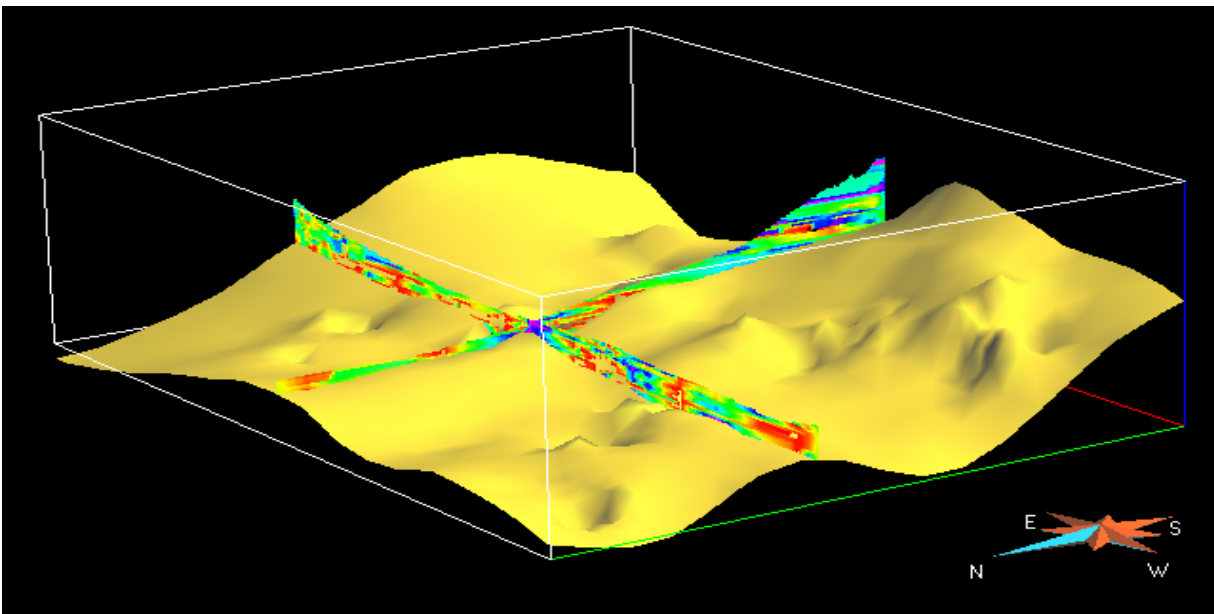


Figure 10. Generated from point data intercepted between the DEM and base of Callabonna, the facies slicer tool is moved throughout the voxel displaying an interpolation indicative of the facies types in the model at any given x,y,z co-ordinate. This slicing tool displays the various facies distribution as dynamically interpolated from the point data. As the tool is manually moved throughout the voxel, the facies distribution alters according to the encountered substrate and is often used to verify how true the isofacies surfaces honour the data. VE=100.

Isofacies surfaces were additionally produced to aid visualising facies distribution. The sliced voxel was used to generate isofacies (Figure 11) of the various facies types as multiple surfaces. These blob-like features can be grouped together to form regions demonstrating similar facies properties which may represent more porous units and less resistive sediments.

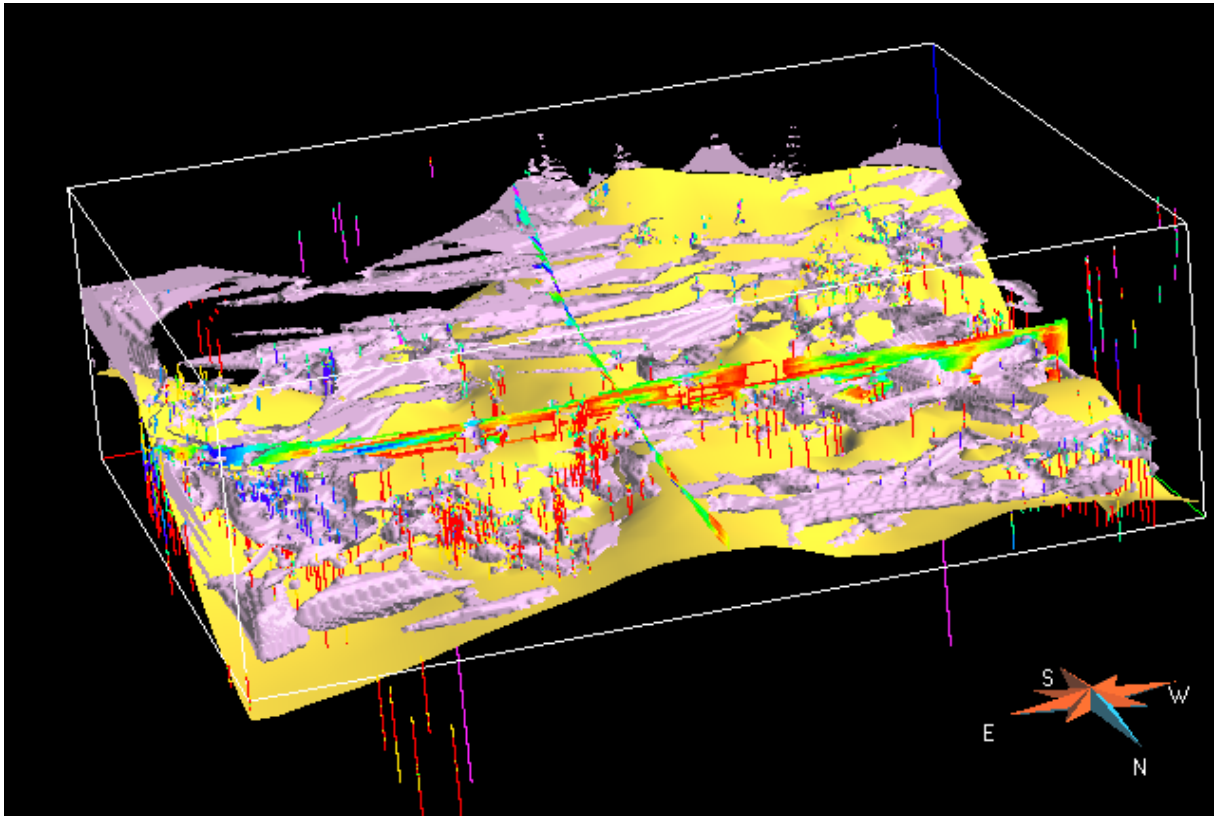


Figure 11. Clay and Sand isofacies fraction as contained within the study area displayed in purple. Through using the slicer tool and well logs, it is possible to quality-audit the isofacies in terms of honouring the drillhole point data. VE=100.

DISCUSSION

The resultant 3D model provided our team with a tool that enabled us to identify regions within the study area as targets for further exploration. Using the predominantly sand and clay fractions, we were able to rapidly visually identify regions with high and low porous sediments typically existing as aquifers and aquitards respectively.

Probably the most important unit to our purposes, are the gravel/sand units, which cover the second largest proportion of the region within the study area. This large unit is generally situated overlying the palaeochannels which may bear some significance to these units being ancient and modern day vectors for sediment and mineral transport. Clay sands are also quite effective vehicles for mineral and fine grained sediment transport. In the western part of the study area around the Billeroo palaeochannel, it appears that the clay sand mixed unit loosely follows the channel shape. Silt however is the most predominant sediment class in the whole study area and in particular appears banded the Billeroo channel region. This banding appearance flows through the entire region as a series of sheet-like features. This may of course be an artefact of the discrete smooth interpolation technique used in

Gocad however due to the sparsity of the data the reliability is not fully certain. Distribution of the clay fraction is fairly restricted to the base and top units in the western Billeroo channel region and a rather large thick unit in the middle of the study area situated around the upper region of the Yarramba palaeochannel. According to the literature on this particular channel, these flat basal clay units are typical within this area serving as a seal for the permeability of groundwater and mineral transport. The silt clay isosurface units are possibly the least abundant in the area. They follow no spatial or geological pattern and do not offer little benefit to the study. It would be a viable study to continue modelling of these highly prospective palaeochannels in higher detail in 3D as this broad scale study has shown its usefulness for highlighting gross features at a broad, regional scale and at a relatively shallow depth.

Improvements

There are a number of ways this model could be significantly improved. The data used in this 3D model is sparse and irregular. Such data produces significant degrees of uncertainty in the model and often makes detailed assessments near impossible and unreliable. To counteract this issue we would suggest the possible interrelated solutions be advised.

Using a geostatistical technique to quantify the degree of uncertainty in the model. At the time of this study the authors had little experience of these complex tools. This approach would utilise 3D Variogram analysis and a Kriging or Simulation technique in place of the interpolation method used.

Reducing the size of the study area. The current area is far too broad for such a small variation in the vertical direction. This is a common problem in 3D modelling and often leads to ungainly models which should be viewed at a regional scale rather than zooming in on a particular area which would be too gross to gain an accurate portrayal of the real-life environment. The smaller study areas would enable more data to be viewed (particularly with finely spaced drillholes) as well increasing the x,y resolution such that the voxel properties can honour the closely spaced drillhole constraints. The aspect ratio of the smaller model area would aid interpretation as the smaller vertical exaggerations necessary to visualise the model will cause less distortion.

CONCLUSION

This study attempted to define the distribution of facies in the Southern Callabonna Sub-basin. The workflow described in this report was used successfully to import data, visually analyse, define the regolith sub-surface structure and to propagate coarse to fine grained isofacies surfaces throughout the model. The use of Gocad's discrete smooth interpolation (DSI) produced variable model reliability resulting from the irregular spatial distribution and anisotropic nature of the dataset and a lack of physical property data. Regions of possible aquifer and aquitard (to a lesser extent) like regions were broadly identified. Once again, the significant limitations of the data posed a problem for the

confidence levels of this model. A more robust result may be achieved by studying the geostatistics of the dataset, densifying the study area and increasing the resolution of the modelled surfaces although this was beyond the scope of this present study.

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APPENDIX A

Excerpt of data from Excel spreadsheet.

hole	tenement	easting	northing	rl	total depth	from	to	from (-rl)	to (-rl)	gravel+sand	silt	clay	other	RGB	total f	weathered rock	depth (-rl)	comments	
WILLIPPA-B	WILLIPPA	323650	6497019	199	95.4	0	2.4	199	197					100	7	0	36.6	162.4	BIG BOULDERS
		323650	6497019			2.4	3.7	196.5	195					100	7	0			LIMESTONE CLAY AN
		323650	6497019			3.7	4.9	195.3	194					100	7	0			LIMESTONE
		323650	6497019			4.9	28.7	194.1	170			100			1	0			PIPE CLAY
		323650	6497019			28.7	30.8	170.3	168	50	10	40			4	0			
		323650	6497019			30.8	31.7	169.2	167	100					2	0			
		323650	6497019			31.7	36.6	167.3	162	50	10	40			4	0			
		323650	6497019			36.6	37.8	162.4	161			100			1	0			
		323650	6497019			37.8	45.4	161.2	154					100	7	0			LAYERS OF SOFT ?S
		323650	6497019			45.4	51.5	153.5	147	40	10	30	20		4	0			SANDY CLAY AND S
		323650	6497019			51.5	54.3	147.4	145	60	10	30			4	0			
		323650	6497019			54.3	55.2	144.7	144	50	10	40			4	0			
		323650	6497019			55.2	61	143.8	138					100	7	0			SOFT SAND ROCK
		323650	6497019			61	89	138	110	50	10	40			4	0			
		323650	6497019			89	94.5	110	105					100	7	0			SOFT SAND ROCK?
		323650	6497019			94.5	95.4	104.5	104					100	7	16			HARD BLUE ROCK
WILLIPPA-C	WILLIPPA	325177	6492424	212	61	0	4.6	211.8	207	50	10	40			4	0			
		325177	6492424			4.6	9.1	207.3	203	30		70			4	0			
		325177	6492424			9.1	15.2	202.7	197			100			1	0			
		325177	6492424			15.2	18.3	196.6	194					100	7	0			LIMESTONE
		325177	6492424			18.3	24.4	193.6	188			100			1	0			PIPE CLAY AND SWE
		325177	6492424			24.4	27.4	187.5	184					100	7	0			YELLOW SAND ROCK
		325177	6492424			27.4	29	184.4	183	50	10	40			4	0			
		325177	6492424			29	42.7	182.9	169		0	100			1	0			
		325177	6492424			42.7	46.9	169.2	165					100	7	0			LIMESTONE WITH HA
		325177	6492424			46.9	61	164.9	151					100	7	10			HARD AND SOFT BA
BORE No3-VWMLPENA		332271	6517954	160	25	0	3	159.8	157	60	10	30			4	0	3.1	156.7	
		332271	6517954			3	25	156.7	135					100	7	2			?BLUE ROCK
BORE No2-VWMLPENA		335446	6517542	125	30.5	0	12.2	125.4	113	40		60			4	0			
		335446	6517542			12.2	18.3	113.2	107					100	7	0			?CONCRETE- POSS.
		335446	6517542			18.3	30.5	107.1	94.9	40		60			4	3			
	WILLIPPA	335800	6495217	138	61.9	0	1.8	138.1	136			60	40	8	0				CLAY AND RUBBLE
		335800	6495217			1.8	15.8	136.3	122					100	1	0			
		335800	6495217			15.8	61.9	122.3	76.3					100	7	3			YELLOW,BROWN,BL

APPENDIX B

GAWK scripts written to convert data

1.

```
# Curnamona_csv_2_gocad_wl.awk
# Author: Malcolm Nicoll
# Date: Aug 2004
# Usage: gawk -f this_prog_name.awk input.csv>output.wl
# Purpose: read csv data file-write gocad well file
# For the CRCLEME Curnamona project
# Change History:
# Date:          Action:          By:
# 24/8/4 Initial creation          Malcolm Nicoll

BEGIN{
FS = ","
getline
getline
name =$3
x=$6
y=$7
z=$8
n=1
f[n]=0+$10
t[n]=0+$11
gravel_sand[n]=0+$14
silt[n]=0+$17
clay[n]=0+$18
other[n]=0+$19
rgb[n]=$20
weathered_rock=$22
n++
}
{
if($6==x&&$7==y){
    f[n]=0+$10
    t[n]=0+$11
    gravel_sand[n]=0+$14
    silt[n]=0+$17
    clay[n]=0+$18
    other[n]=0+$19
    rgb[n]=$20
    n++
}
else{
print "GOCAD Well 0.01"
print "HEADER{"
    printf "name: %s\n", name
    print "}"
    printf "WREF %6.1f %7.1f %4.1f\n", x,y,z
    print "DPLN 0"
    printf "PATH 0 %f 0 0\n", z
    printf "PATH %f %f 0 0\n", t[n-1], z-t[n-1]
if (weathered_rock>=.01){printf "MRKR weathered_rock 1 %f\n", weathered_rock}
    for(i=1; i<=n-1; i++){
        printf "ZONE %s %3.2f %3.2f %d\n", rgb[i],f[i], t[i], i
    }
    print ""
    print "WELL_CURVE"
    print "PROPERTY gravel_sand"
    print "UNITS meters meters/sec "
print "PROPERTY_CLASS_HEADER gravel_sand {"
print "*low_clip:0"
print "*high_clip:100"
print "*pclip:99"
print "}"
}
```

```

        for(i=1; i<=n-1; i++){
            printf "REC %4.1f % 1.1f \n", f[i],gravel_sand[i]
            printf "REC %4.1f % 1.1f \n", t[i]-.1,gravel_sand[i]
        }
print "END_CURVE"

print "WELL_CURVE"
    print "PROPERTY silt "
    print "UNITS meters meters/sec "
print "PROPERTY_CLASS_HEADER silt {"
print "*low_clip:0"
print "*high_clip:100"
print "*pclip:99"
print "}"
for(i=1; i<=n-1; i++){
    printf "REC %4.1f % 1.1f \n", f[i],silt[i]
    printf "REC %4.1f % 1.1f \n", t[i]-.1,silt[i]
}
print "END_CURVE"
print "WELL_CURVE"
    print "PROPERTY clay "
    print "UNITS meters meters/sec "
print "PROPERTY_CLASS_HEADER clay {"
print "*low_clip:0"
print "*high_clip:100"
print "*pclip:99"
print "}"
for(i=1; i<=n-1; i++){
    printf "REC %4.1f % 1.1f \n", f[i],clay[i]
    printf "REC %4.1f % 1.1f \n", t[i]-.1,clay[i]
}
print "END_CURVE"
print "WELL_CURVE"
    print "PROPERTY other"
    print "UNITS meters meters/sec "
print "PROPERTY_CLASS_HEADER other {"
print "*low_clip:0"
print "*high_clip:100"
print "*pclip:99"
print "}"
for(i=1; i<=n-1; i++){
    printf "REC %4.1f % 1.1f \n", f[i],other[i]
    printf "REC %4.1f % 1.1f \n", t[i]-.1,other[i]
}
print "END_CURVE"

        print "END"
        print ""

        name =$3
        x=$6
        y=$7
        z=$8
        n=1
        f[n]=$10
        t[n]=$11
        gravel_sand[n]=$14
        silt[n]=$17
        clay[n]=$18
        other[n]=$19
        rgb[n]=$20
        weathered_rock=$22
        n++
    }
}
END{}

```

2.

```

# wellzone_2_rs_points.awk
# Author: Malcolm Nicoll

```

```

# Date: Aug 2004
# Usage: gawk -f this_prog_name.awk input.wl>output.vs
# Purpose: read zone data from gocad well file-write gocad point(.vs) file
# For the CRCLEME Curnamona project
# Change History:
# Date:          Action:          By:
# 24/8/4 Initial creation          Malcolm Nicoll
#-----
BEGIN{
# enter sample rate here
sr=.5
#-----
}
{
if ($1 ~ /WREF/){
x=$2
y=$3
z=$4
}
if ($1 ~ /ZONE/){
sm=$4-$3
s=sm/sr
printf "%6.1f %7.1f %5.1f %d\n", x, y, z-$3, $2
for (ss=sr; ss<=sm-sr;ss=ss+sr){
printf "%6.1f %7.1f %5.1f %d\n", x, y, (z-$3)-ss, $2
}
printf "%6.1f %7.1f %5.1f %d\n", x, y, z-$4, $2
}
}
}
END{}

```

APPENDIX C

GOCAD well format

```
GOCAD Well 0.01
HEADER{
name: ORB-105
}
WREF 380398.0 6482008.0 139.7
DPLN 0
PATH 0 139.740000 0 0
PATH 48.000000 91.740000 0 0
ZONE 4 0.00 36.00 1
ZONE 4 36.00 48.00 2

WELL_CURVE
PROPERTY gravel_sand
UNITS meters meters/sec
PROPERTY_CLASS_HEADER gravel_sand {
*low_clip:0
*high_clip:100
*pclip:99
}
REC 0.0 55.0
REC 35.9 55.0
REC 36.0 40.0
REC 47.9 40.0
END_CURVE
WELL_CURVE
PROPERTY silt
UNITS meters meters/sec
PROPERTY_CLASS_HEADER silt {
*low_clip:0
*high_clip:100
*pclip:99
}
REC 0.0 50.0
REC 35.9 50.0
REC 36.0 0.0
REC 47.9 0.0
END_CURVE
WELL_CURVE
PROPERTY clay
UNITS meters meters/sec
PROPERTY_CLASS_HEADER clay {
*low_clip:0
*high_clip:100
*pclip:99
}
REC 0.0 40.0
REC 35.9 40.0
REC 36.0 60.0
REC 47.9 60.0
END_CURVE
WELL_CURVE
PROPERTY other
UNITS meters meters/sec
PROPERTY_CLASS_HEADER other {
*low_clip:0
*high_clip:100
*pclip:99
}
REC 0.0 0.0
REC 35.9 0.0
REC 36.0 0.0
REC 47.9 0.0
END_CURVE
END
```