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Naturally Fractured Tight Gas Reservoir Detection Optimization

Quarterly Report
October 1 - December 31, 1995

Work Performed Under Contract No.: DE-AC21-93MC30086

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
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DISCLAIMER

Disclaimer

QUARTERLY STATUS REPORT
Period of Performance: October 1, 1995 - December 31, 1995
Date of Submission: January 31, 1996

CONTRACT NO:

DE-AC21-93MC30086

CONTRACTOR:

Advanced Resources International, Inc.
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CONTRACT NAME:

Naturally Fractured Tight Gas
Gas Reservoir Detection
Optimization

CONTRACT PERIOD:

09/30/93 - 03/31/97

CONTRACT OBJECTIVE: No Change

TECHNICAL APPROACH CHANGES: No Change (None)

3D SEISMIC ACQUISITION PROGRAM:

Bid adjustments, based on moving the location of the survey, have been received from the four companies that had previously bid on the 3D acquisition. Two companies, Western Geophysical and Northern Geophysical did not change their bids. Capilano and Grant Geophysical did change their bids to take into account turnkey shot hole drilling. Based on the normalization of key acquisition chargeables as indicated in Table 1, attached, crew availability and experience in the project area, I recommend that Western Geophysical be awarded the contract for seismic acquisition, subject to completion of an acceptable contract and approval by the DOE.

Discussion

As part of the rebidding process, the shot hole drilling was requested as a turnkey item. Grant Geophysical and Capilano Geophysical bids were increased as a result of this request. Costs provided by each vendor were then normalized by including costs for those items required for complete survey acquisition. These items include on-site processing/quality assurance through the use of Micromax/Vista systems, additional permitting costs, hole plugging costs, additional drilling or supervision costs and any other charges not specifically handled under the general acquisition bid. When these items were taken into account the bids range from a high of $471,900 (Capilano Geophysical) to a low of $346,250 (Western Geophysical). The Western Geophysical bid was $26,785 less than the next closest bidder, Grant Geophysical and $47,760 less than the Northern Geophysical bid. The difference between the Western bid and the Capilano bid is $125,650.

TABLE 1 - Seismic Acquisition Bid Comparison

Item	Capilano Geophysical	Grant Geophysical	Northern Geophysical	Western Geophysical
Basic Acquisition	$415,000	$352,360	$371,110	$321,000
Weather Days	$32,400	$12,000	$6,000	$0
Permit Agents 2@10 days	$11,250	$5,250	$9,900	$10,500
Client Testing .5 day	$1,100	$925	$1,000	$1,000
Hole Plugging Materials	$8,400	$0	$0	$0
Additional Drilling Costs	$0	$0	$0	$10,000
Micromax/Vista 5days	$3,750	$2,500	$6,000	$3,750
Total Acquisition Cost	**$471,900**	**$373,035**	**$394,010**	**$346,250**
Cost Difference	$125,650	$26,785	$47,760	$0
Percent Difference	36.3%	7.7%	13.8%	0.0%

Each of the contractors providing bids on this contract have the necessary equipment, experience and technical capability for the required performance objectives under this portion of the contract, and it is felt that all would provide acceptable data for analysis. All are able to meet the necessary acquisition timing for February-March acquisition. Cost is then the primary factor in awarding Western Geophysical the contract.

The contract will be awarded to Western Geophysical contingent upon: 1) DOE approval and 2) final contract negotiations. Issues such as heliportable drilling and site access must also be resolved before contract award. Another on-site visit by the drilling contractor to establish the need for heliportable drilling is planned for early January. A permit agent will talk with surface owners to obtain permission for surface access. We anticipate a problem with one land owner who has established a reputation for being difficult to work with. A meeting will be set up with the BLM to clarify dates for deer and elk winter feeding habitats and restrictions on clearing bush for drilling access.

Assuming we are successful in all our endeavors, I anticipate source point drilling to commence middle February and the acquisition to begin mid-April.

National Environmental Protection Act

Preparation of the NEPA document has been awarded to Blackhawk Geosciences. As Blackhawk previously submitted two NEPA documents that were quickly accepted by the DOE, they are the logical candidate to perform the task. Although the NEPA preparation is relatively simple and fast, delays may be expected due to the partial government shut-down.

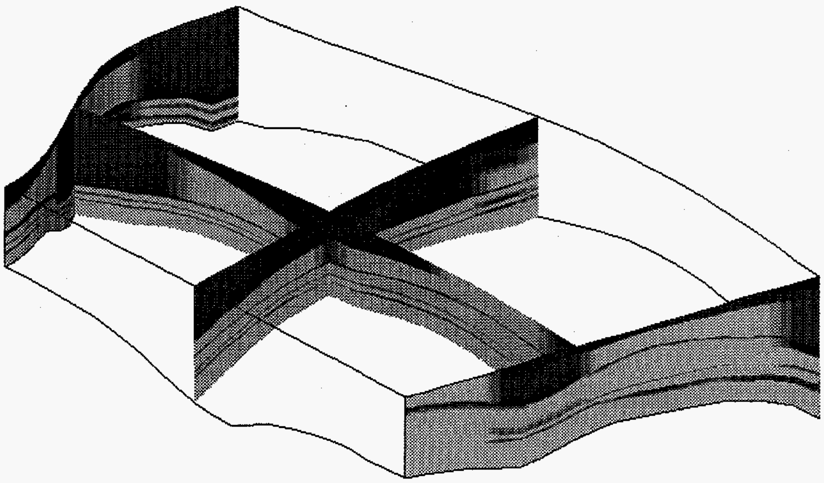
3D BASIN MODELING:

Three-dimensional basin simulator

The incremental stress solver has been upgraded through a new solution technique we have developed that is much less memory-intensive, faster, and is more robust even for incompactable rocks and for large changes of rock properties between beds. The technique is based on an iterative scheme for subsets of the variables (deformation velocity vector and stress tensor). Furthermore, the linear solution part of the module was completely changed to a better technique that made the code a total of more than 20 times faster and it occupies less than 1/5 the memory than it did earlier. We are now incorporating this advanced code into CIRF.B and testing it. Now stress calculations should only occupy less than 20% of the total CPU time.

A problem with the sediment input module has been identified that is related to an incompatibility of grid resolution and the radius of curvature of the basin's lower boundary and an analogous problem when beds pinch off; a smoothing method and grid refinement has been set forth to address this problem. The smoothing algorithm has been implemented and tested and now allows for changes in sedimentation rate and character consistent with the grid resolution. An additional technique has been developed that optimizes (adapts) the grid; this improvement will also allow for erosion, a key factor missing in our previous formulation. A preliminary simulation using these sediment input improvements is seen in Fig. 1.

(a)



(b)

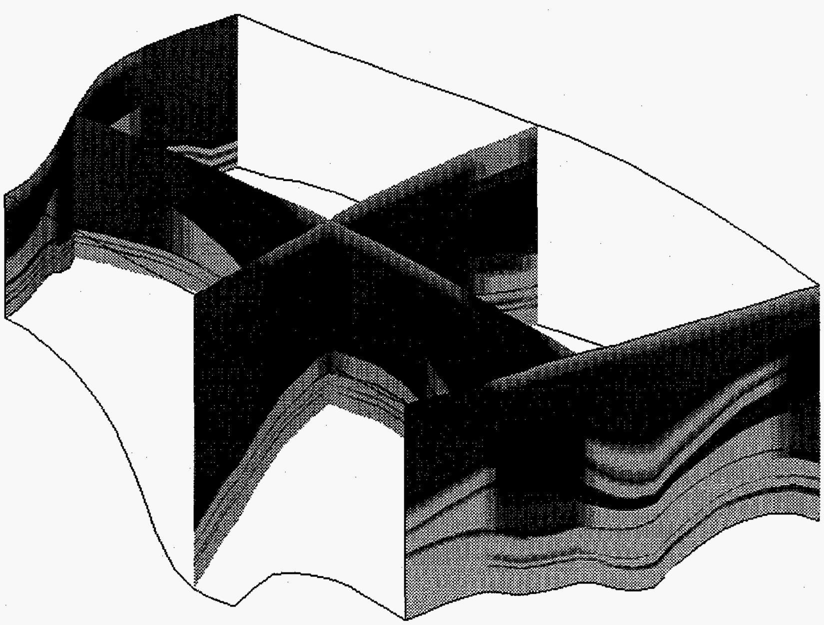


Fig. 1 Cross sections showing different lithologies (light = fine-grained beds, dark = course-grained beds). (a) After 6.99 MY of simulation, maximum thickness of the sediment is 969 M. (b) After 16.1 MY of simulation, maximum thickness of the sediment is 2065 M.

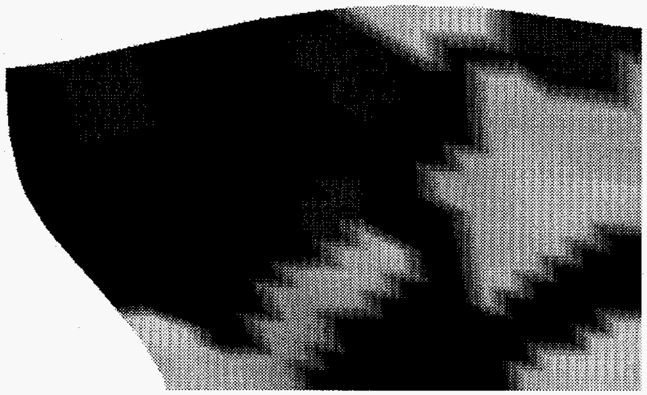


Fig. 1(c) Top view showing variation of sediments at 69.97 MY (light = fine-grained sediments, dark = course-grained sediments). The size of the domain is 120x90 km. Irregularity of the boundaries between sediments are due to the resolution of the graphics.

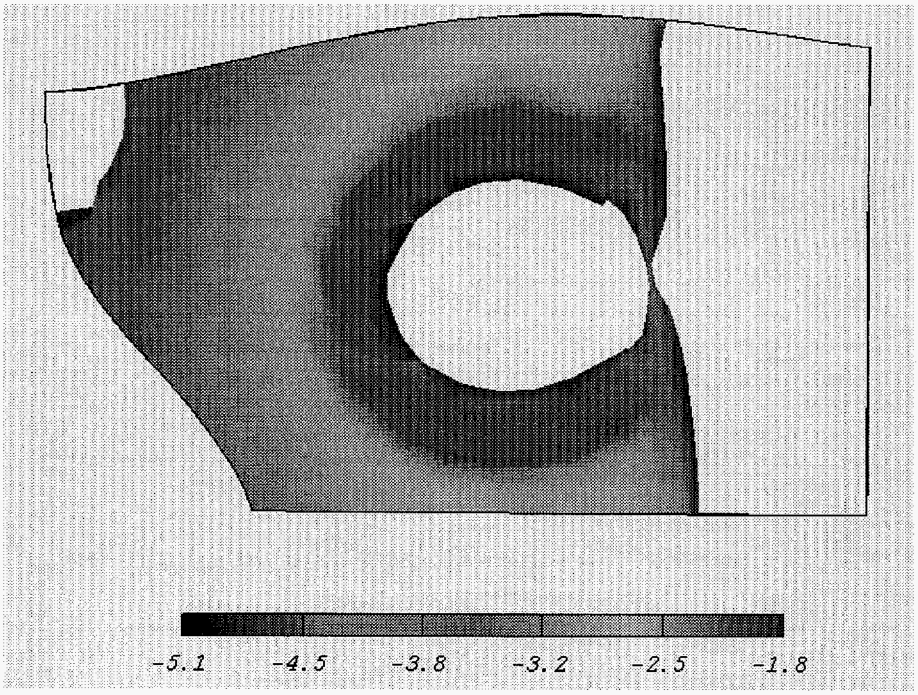


Fig. 2(a) Isosurfaces at 10 MA for a basin 70 km x 120 km. Average fracture length of 1.5 cm. Gray level indicates depth to surface.

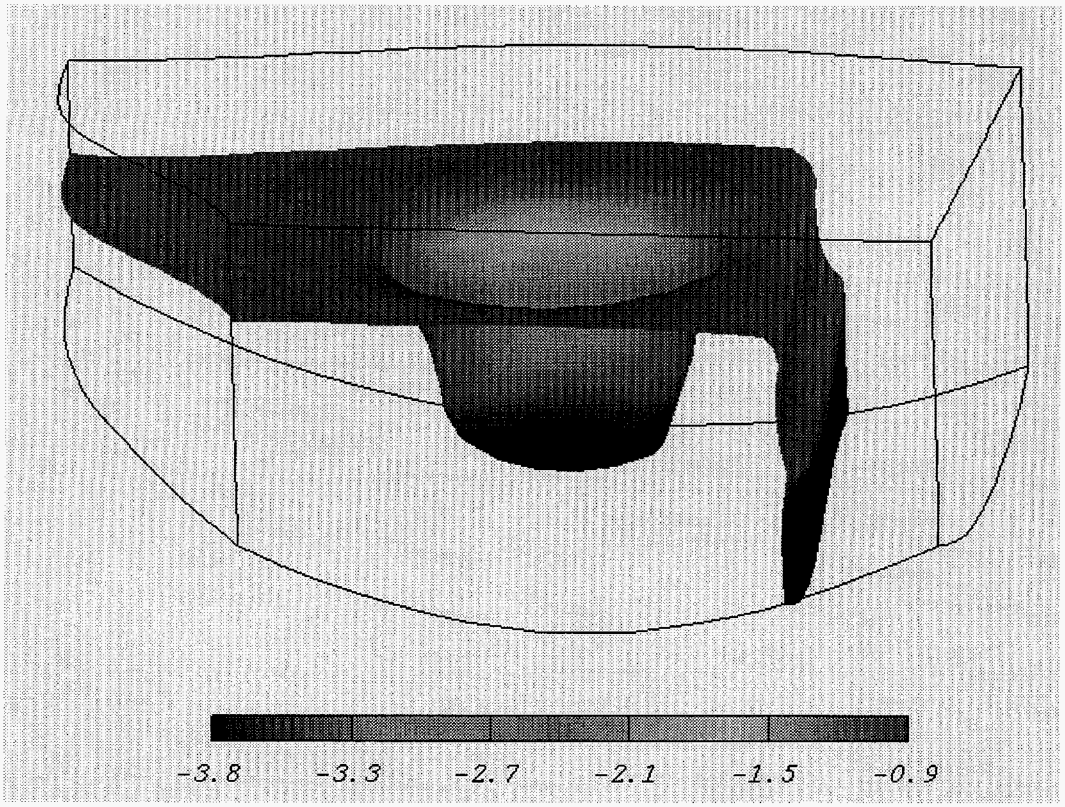


Fig. 2(b) As in 2(a), but with overpressure at 75 bars.

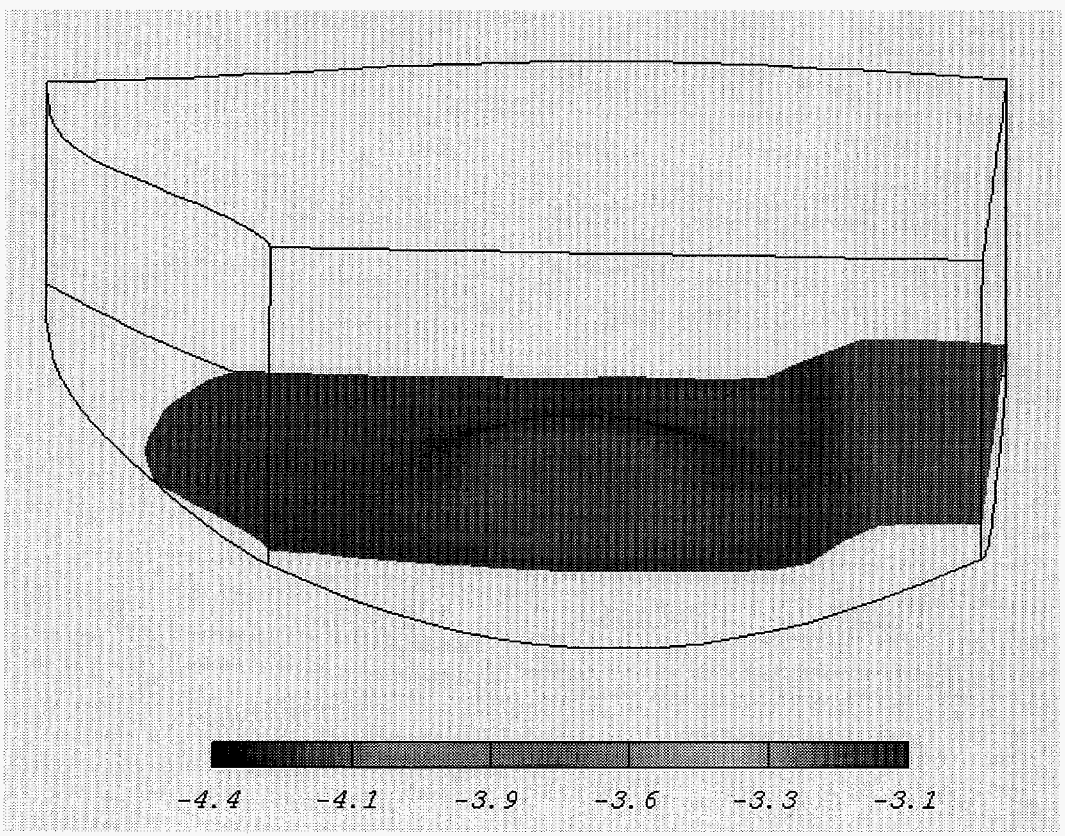


Fig. 2(c) As in 2(a), but with temperature of 127°C.

A more advanced model of fracture kinetics involving the statistics of a swarm of fractures has been implemented. Simulation on a simple test basin shows results using this module (Fig. 2). This simulation also shows how the temperature isosurface (Fig. 2c) is elevated within the fault region because of the upswelling geothermal fluids there.

Data analysis and data base

New well data have been analyzed and are being formatted for input into the sediment history recreation module; this will bring the number of wells used in our Piceance study to about 70, yielding what we believe to be a rather refined (high resolution) data set. In Fig. 3, we see the location of about 50 of these wells. Figs. 3-5 show aspects of the resulting predicted sediment history and features of our graphical display software developed for this project using the AVS graphics software development package.

In order to create the best possible stratigraphic and lithologic data set for three-dimensional simulations, we are constructing three sets of well files of varying degrees of detail for the southern part of the Piceance Basin. Set One consists of twenty-nine wells with relatively detailed stratigraphic and lithologic information, particularly for the Mesaverde Group. This set has been constructed and has been used in preliminary simulations. Limited lateral continuity of some units, as well as difficulties in correlating units laterally because of insufficient well density, led to the inclusion of additional well data (from the Texas Bureau of Economic Geology). These additional twenty-seven wells contain limited stratigraphic data, specifically the depths to the maximum flooding surface at the bottom of the Williams Fork Formation, and two other flooding surfaces within the same unit. Thus, Well Set Two combines the twenty-nine and twenty-seven wells for a total of fifty-six (Figure 3), and it has a greater well density than Well Set One. In order to integrate the two different types of data, stratigraphic horizons in wells of Set One were correlated with the Williams Fork flooding surfaces, and the rest of the vertical data was removed (Figure 4). Thus Set Two will have more limited vertical detail than Well Set One. Set Two will be used to refine and constrain the sequence stratigraphic model, and it will also be used to create Well Set Three. Set Three will be constructed by taking wells from Set Two that fill in horizontal gaps in Set One, and interpolating stratigraphic and lithologic detail from the nearest wells of Set One. Thus, Well Set Three will provide better well density than Set One, and better stratigraphic detail than Set Two. This well set will be the ultimate data set for the three-dimensional simulation input for this project.

Some new modules have been added to our sediment history graphical analysis package (arbitrary slicing and flexible contouring) that greatly advances our power to critically analyze the computer generated sediment history recreation.

A calibration of our failure criteria for a full suite of relevant rocks is still in progress. As the range of rock types covered by our calibration increases, the rock property data set in our three-dimensional simulator is continuously updated so that simulations can always be based on the best available rock mechanics data.

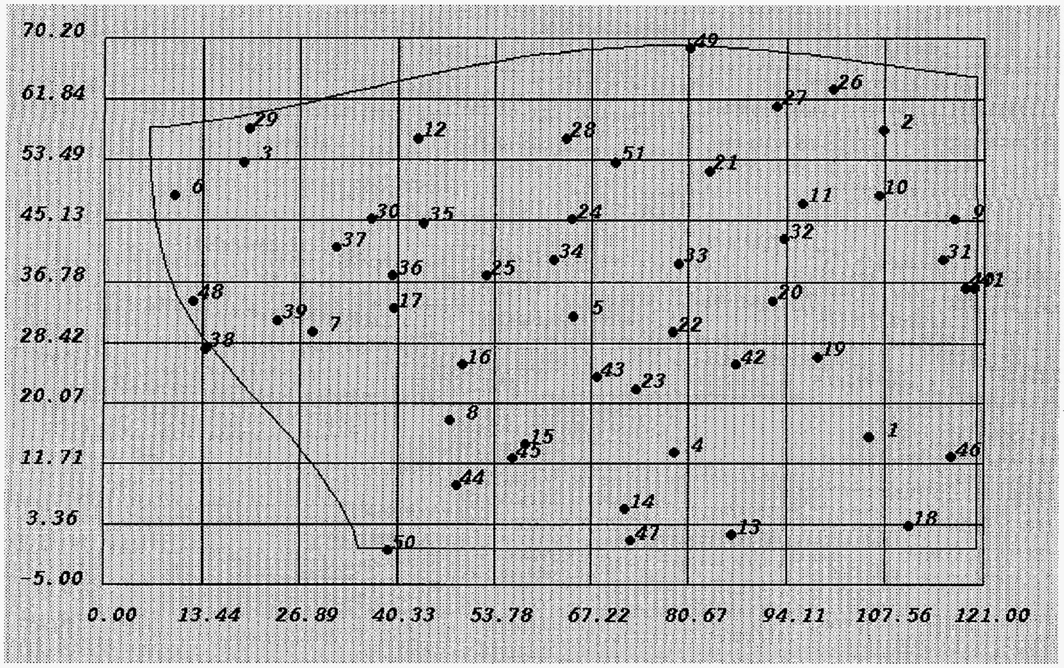


Fig. 3 Distribution of wells with available stratigraphic and/or lithologic data in the southern part of the Piceance Basin simulation domain.

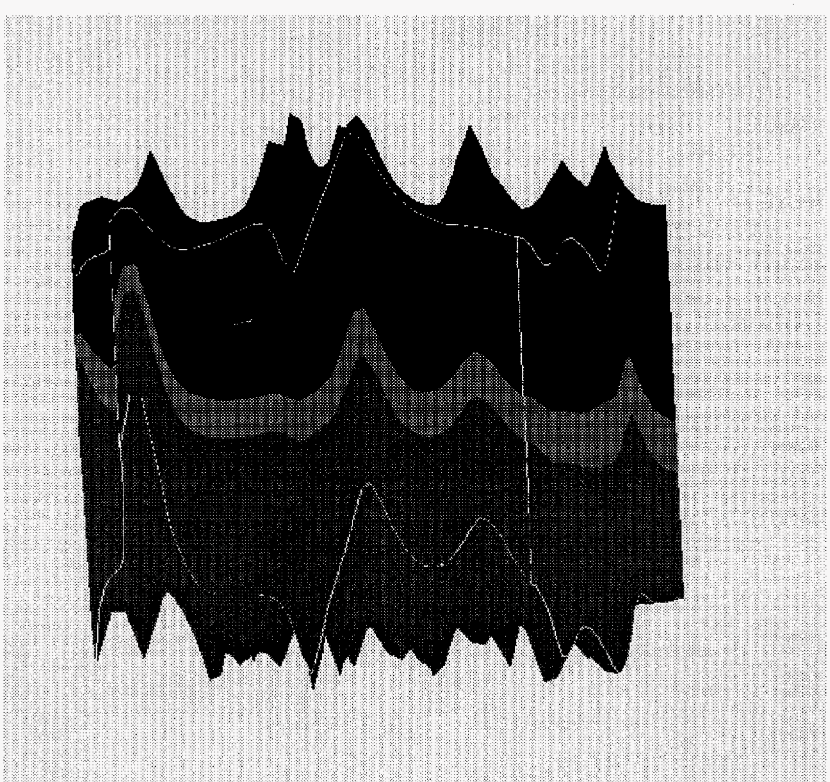
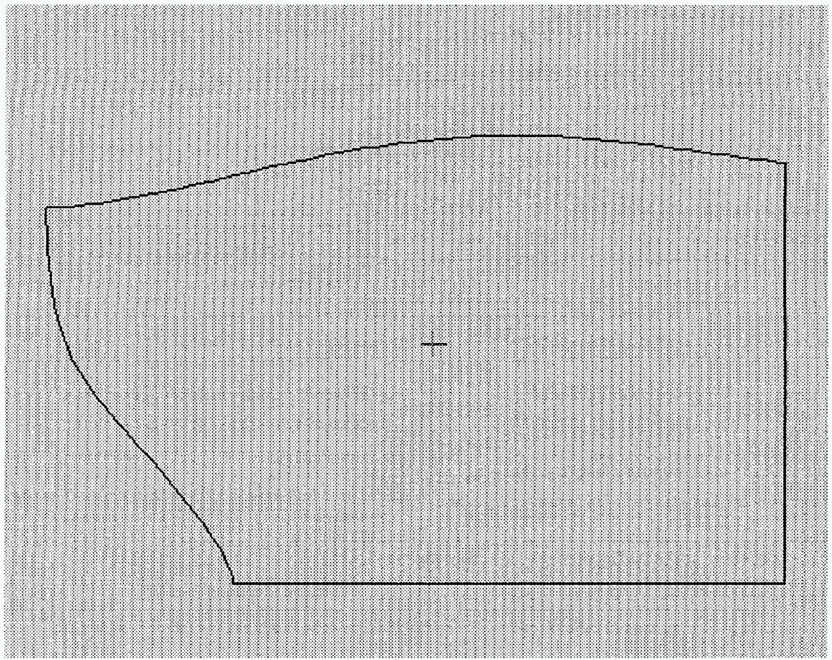


Fig. 4 A three-dimensional block diagram using data from Well Set Two. The lowermost unit comprises pre-Williams Fork - Mesaverde units, including the Iles Formation and Mancos Shale; the middle unit comprises most of the Williams Fork Formation, which contains the source rocks and many of the reservoir rocks; and the uppermost unit comprises primarily Upper Cretaceous-Tertiary units.

(a)



(b)

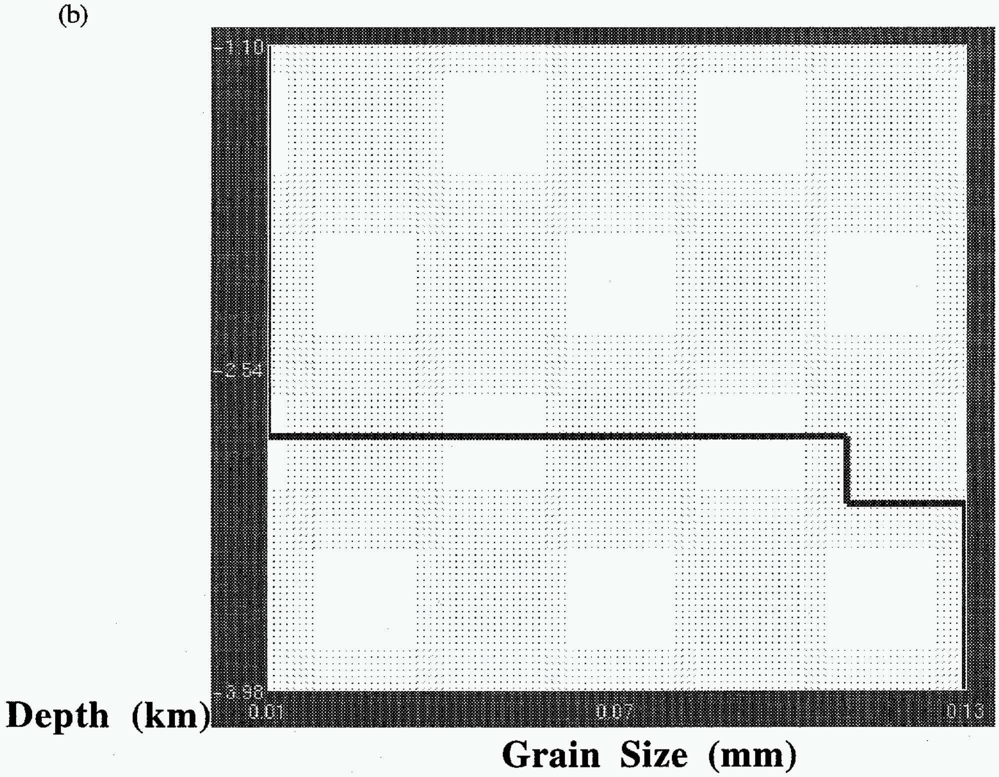


Fig. 5 (a) Location of vertical grain size profile; (b) Grain size vs. depth at location indicated in (a) for range of depth from 1 to 4 km (vertical axis). The grain size values for each stratigraphic layer are taken from average grain size values of specific units within each layer, and will require further calibration.

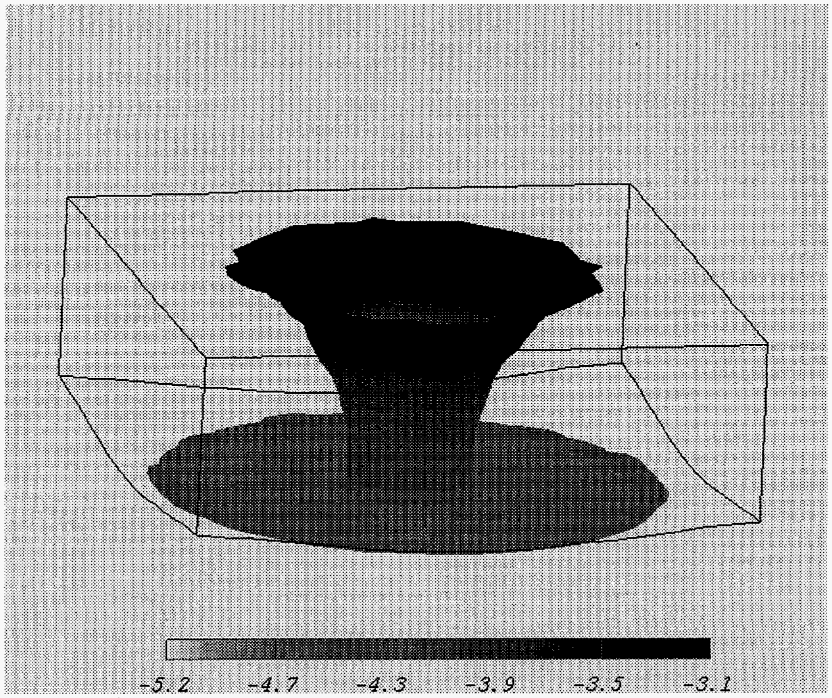


Fig. 6(a) Multi-phase reaction-transport simulation showing the effect of methane generation in a domain 100 km x 100 km in map view by 5 km deep after 100 MA. The source rock was 1 km thick and resided at the bottom of the domain (the latter in a bowl shape). The isosurface of gas saturation of .002 shows most methane was produced in the deeper part of the bed (because of the higher temperature there) and most interestingly a vase-like morphology arising from liquid dropping down in the center, breaking up the single column of rising methane-rich water and gas (the latter being less mass-dense).

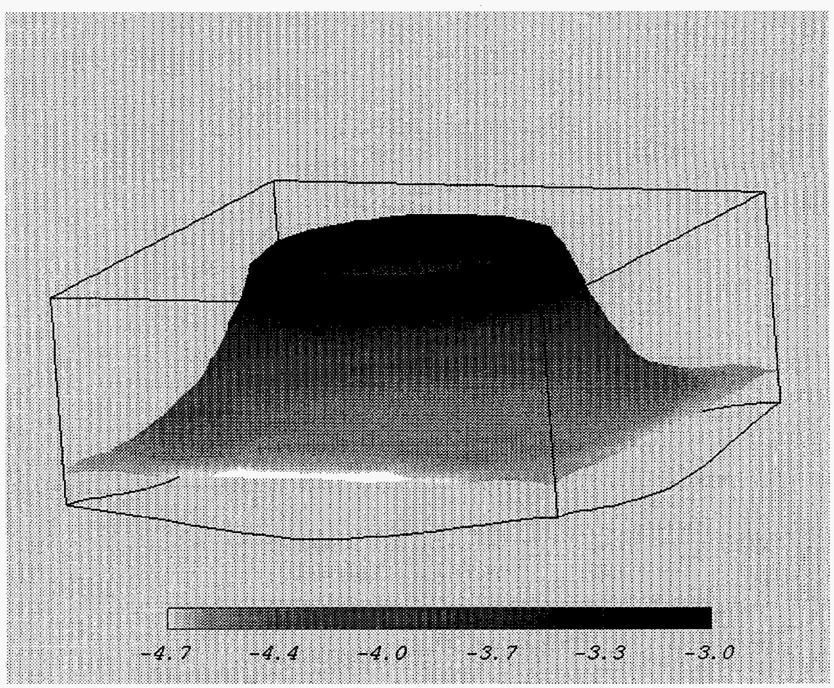


Fig. 6(b) As in 6(a), but for isosurface of methane molar concentration at 1.2×10^{-5} molar.

Organic reactions and multi-phase flow

The three-dimensional, multi-phase reaction-transport module has been made more efficient; testing for three and more species has been started for aqueous and gas phase systems, as has testing of the capillarity and relative permeability phenomenologies. Simulations on the 100 MY time scale show overpressuring of source rocks and escape to neighboring beds. An example is seen in Fig. 6. A more general kerogen kinetic model and module have been designed and implementation will soon be completed. Creation of the multi-phase reaction-transport simulator and organic kinetics model and data base are voluntary tasks added after the project began to insure greater project success.

Forecast

All elements of the subcontract are essentially on schedule. Original goals are being exceeded because of the additional efforts being expended in the three-dimensional multi-phase module and certain aspects of the sediment history recreation modules. Full simulations of the Piceance basin should commence in early February 1996. (In fact, most ongoing testing is being done using Piceance data.)

OPEN ITEMS: None

David Decker, Principal Investigator