Quarterly Status Report

**Quarterly Report
October 1 - December 31, 1996**

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

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

By
Advanced Resources International, Inc.
165 South Union Boulevard, Suite 800
Denver, Colorado 80228

MASTER

19980313 139

Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

QUARTERLY STATUS REPORT
Period of Performance: October 1 - December 31, 1996
Date of Submission: February 2, 1997

CONTRACT NO.

DE-AC21-93MC30086

CONTRACTOR:

Advanced Resources International, Inc.
165 South Union Boulevard, Suite 800
Denver, Colorado 80228

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

RULISON 3-D P-WAVE DATA PROCESSING:

Data tapes were shipped from Western Geophysical for interpretation. The datatapes include wiggle trace data (two-azimuth volumes of post-stack time migration seismic data) and velocity data (2 azimuths' stacking velocity cubes).

The two-azimuth volumes are those source-receivers in the "fast" P-wave velocity direction, N150E (N30W) and the "slow" P-wave velocity direction (N60E), as picked from super gathers that scanned over azimuth, termed "azimuth bin gathers." Spatial variability in the direction of the "fast" P-wave and the spatial variability in the magnitude of the difference of the two velocities are observed in the Rulison 3D dataset. The difference of interval velocity with azimuth is one of the more robust, and preferred, measures of seismic anisotropy. The stacking velocity cubes for each azimuth are used to determine the interval velocities of the two different azimuths.

We also observed in the azimuth bin gathers significant azimuthal variations in amplitude (brightening and dimming) which were centered on the two chosen azimuths. This is very important because it indicates field data support that the amplitude anisotropy is oriented the same as the velocity anisotropy. When the cause of the velocity anisotropy is the same as the cause of the amplitude anisotropy, then the velocity and amplitude anisotropy will be aligned. The Western Geophysical "Fractogram" approach will further test the hypothesis (and the preliminary field data observation) that the two observations have the same orientation. However, if different causes exist for velocity versus amplitude anisotropy, then the two effects need not be aligned. In the current model, vertical aligned gas-filled fractures are the cause of the velocity and amplitude anisotropy.

The seismic attribute that best approximates the Estimated Ultimate Recovery is the ratio of the interval velocities in the gas-saturated Mesaverde interval (the "Z" reflector to the top of Cameo Coal reflector). This result is consistent with the findings of the other DOE/Morgantown project, in the Madden Field, Wind River, WY: the ratio of the interval velocities (perpendicular the fractures, or the slow direction, divided by the parallel to fractures direction, that is, the fast direction) showed the best correlation to the EUR, as furnished by a population of 12 wells (rank A and B, >15 BCF and 15 > 8 BCF, respectively), and 7 non-commercial or dry hole wells.

We have also examined the reflection amplitude data and have determined that there appears to be a near-surface effect which is present on all stacked reflectors' amplitudes and in all interval stacked amplitude measurements down to the Corcoran (about 1.5 sec. below the target zone). This near-surface effect appears to be caused by an anisotropic weathering layer, which is affecting the quality of transmission of reflection signal, dependent upon azimuth of source-receiver. Therefore, we are devising techniques, adapted from industry conventional standards, to deal with this problem. The consequence of this near-surface effect is that AVO (amplitude variation with offset) analysis and reflection strength analysis is suspected to be problematic until this problem is solved.

On October 10th, a meeting was held at Barrett Resources. In attendance were representatives from DOE, Barrett Resources, Advanced Resources International, Lynn, Inc., and Western Geophysical. The status of the project to date was presented. The high-resolution aero-magnetic data is useful for detecting basement block trends. Where basement blocks are juxtaposed, high fracture density may occur in the overlying sedimentary section due to re-activated movement along prior zones of weaknesses. The 3D P-wave two-azimuth datasets were presented, which included the observed similarity between the interval velocity anisotropy the Estimated Ultimate Recovery, as calculated by ARI. The P-wave interval velocity anisotropy is determined by the ratio of the interval velocities (N60E azimuth/N150E azimuth) between the Z marker (top of gas-saturated Mesaverde) to T/Cameo Coals. The ratio of the interval velocities is one measure of the difference by azimuth of the interval velocity. Where the N150E was the faster velocity, desirable EURs were observed.

The N150E azimuth is also the observed fault trend azimuth for the faults that cut the top of the Cameo Coals and the Rollins (a market beneath the Cameo Coals). The extension of the faults mapped at the top of the Cameo Coals up into the gas-saturated Mesaverde may be the mechanism associated with the high-fracture density interpreted as existing, based upon the velocity anisotropy.

The N150E azimuth is also the observed major fold axis trend in the major broad fold at Rollins level, seen directly S/SE of the 3D P-wave area.

Slower interval velocities were observed in the gas-saturated Mesaverde section (Z-Cameo Coals) as compared to the shallower Mesaverde section (Mesaverde to X, X to Z). This observation indicates to us that seismic maps of the top of the gas-saturated Mesaverde are a reasonable output product. Since operators in the area have difficulty in picking the top of the gas saturated Mesaverde from wireline log data, assistance from 3D P-wave seismic would be appreciated.

In November, 1996, the near offset migrated volumes (N150E and N60E) and the far offset migrated volumes (N150E and N60E) were calculated at Western Geophysical. Of the four tapes initially shipped, three tapes were read in successfully at Lynn, Inc., but the fourth tape had errors. We

requested a new tape and waited for its arrival. (It arrived in early December.) Preliminary inspection of the three legible tapes showed that the seismic time picks for the horizons of interest, as picked on the full-offset stacked migrated volumes, correlated well with the desired peaks and troughs on the offset-limited volumes. From the good match of traveltimes from the full-offset volumes to the far-offset volumes, we conclude that the stacking velocities are quite good and that residual error in the normal moveout is not a problem.

The new well, RMV 68-21, was logged including P-wave velocities (sonic log) and Barrett Resources provided the digital version of the logs. We loaded it and made a synthetic, which we tied to the 3D P-wave volume. The seismic markers already picked correlated with the tops supplied by Barrett Resources, thus indicating that we are on the correct seismic horizons for the geologic formations of interest.

Based upon a phone conversation with Dave Decker, the following two maps were re-examined:

1. The Interval Z to Cameo Coals: transit time anisotropy, time difference at the Cameo (N60E-N150E) minus time difference at the Z (N60E-N150E).
2. The ratio of the interval velocities, N60E/N150E from Z-Cameo.

An inverse relationship was observed in the color schemes, 1-greens (cold colors) to 2-yellows, oranges (warm colors).

Since the color codes were chosen to indicate consistency with "model" of N150E being the open fracture direction and/or the maximum horizontal stress direction, the data thus imply that the travel time anisotropy is going the opposite way from the moveout velocity anisotropy. This was also observed in the Madden 37 sq. mile survey for the LFU.

A faster stacking velocity tends to make the stacked event appear later in time, compared to a slower stacking velocity. Therefore, the faster stacking velocity azimuth tends to have the longer transit times on the stacked seismic data. The consequence of this is: the moveout velocities are interpreted as indicating preferential stiff or compliant directions, and thus predicting open fracture azimuth. The travel times are affected by the stacking velocity used in processing and a greater interval transit time, as measured from stacked data, should not be interpreted as indicative of a lower interval velocity, that is, more compliant direction.

In December, 1996, the last tape of a series of four tapes (the nears and fars, migrated volumes, two azimuth processing) was loaded and reformatted. Analysis of the amplitude variation with offset and azimuth proceeded for reflectors of interest. The difference of the near offset volumes, with azimuth, were calculated for reflectors of interest. The difference of the near offset volumes, with azimuth, were calculated for reflectors of interest, as well as the difference of the far offset volumes with azimuth. AVO gradient maps were calculated using the typical approximation of "Far offset minus Near offset" method. (In January, the relationships of these numbers to EUR is being investigated.)

Analysis of the stacked two-azimuth migrated volumes continued with calculation of the interval velocities and their ratio by azimuth for intervals of interest for the Cameo Coals-Rollins-Corcoran

intervals and interval frequency analysis (differences by azimuth) were investigated. The nature of the amplitude difference by azimuth, which has a general trend that persists from shallow to deep, was also investigated to determine how to best characterize it and then how to best remove it.

Two meetings were held with Ken Craft, Western Geophysical, in the Houston office. The preliminary amplitude-Fractogram results were shown: these showed the variation of amplitude with azimuth, for the far offsets after scaling by the variation of the near offset amplitudes with azimuth. The orientation of the anisotropy and its magnitude can be estimated through this technique. However, a localized persistent feature appeared. Persistent (in one spatial location, persistent with increasing time) features are interpreted to be near-surface or shallow effects that are not related to geology in the target zone. The minimization of such features, through processing, is considered appropriate. Mr. Craft is looking into methods to accomplish such.

A meeting was held with Roger Reinmiller on December 13, 1996, in Houston. The preliminary results of the borehole image log (cibil) of Western Atlas were presented by Roger. Xeroxes of significant portions of the log were made. The shallowest depth logged with the 2 arm caliper was 500 feet from 570-590', the two calipers read different hole diameters, indicating an elliptical borehole. We interpret this to indicate the presence of unequal horizontal stresses. From depths 2,650-2,890, an elliptical borehole is observed, which is interpreted to indicate the presence of unequal horizontal stresses. From depths 2,930-3,180 feet, an elliptical borehole is observed. We interpret this to indicate the presence of unequal horizontal stresses.

Unequal horizontal stresses can cause azimuthal anisotropy (as measured in P-wave reflection seismic data). The orientation of the borehole elongation will predict the orientation of the seismic anisotropy. The long axis of the borehole is the direction of minimum horizontal stress; the short axis of the borehole is the direction of maximum horizontal stress. The more closed fractures are normal to the maximum horizontal stress; the more open fractures are normal to the minimum horizontal stress, that is, parallel to the maximum horizontal stress. The fast P-wave direction is parallel to the maximum horizontal stress, or parallel to the open fractures.

OPEN ITEMS: None

David Decker

M98050549

Report Number (14) DOE/MC/30086-56 24

Publ. Date (11) 1990 7 10

Sponsor Code (18) DOE/FE, XF

JC Category (19) UC-101, DOE/ER

DOE