An Advanced Fracture Characterization and Well Path Navigation System for Effective Re-Development and Enhancement of Ultimate Recovery from the Complex Monterey Reservoir of South Ellwood Field, Offshore California

Quarterly Technical Progress Report

Reporting Period Start Date: **Oct. 1, 2001**

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Progress Report October 1, 2001-December 31, 2001

Disclaimer

Abstract

Venoco Inc, intends to re-develop the Monterey Formation, a Class III basin reservoir, at South Ellwood Field, Offshore Santa Barbara, California.

Well productivity in this field varies significantly. Cumulative Monterey production for individual wells has ranged from 260 STB to 8,700,000 STB. Productivity is primarily affected by how well the well path connects with the local fracture system and the degree of aquifer support. Cumulative oil recovery to date is a small percentage of the original oil in place. To embark upon successful re-development and to optimize reservoir management, Venoco intends to investigate, map and characterize field fracture patterns and the reservoir conduit system. State of the art borehole imaging technologies including FMI, dipole sonic and cross-well seismic, interference tests and production logs will be employed to characterize fractures and micro faults. These data along with the existing database will be used for construction of a novel geologic model of the fracture network. Development of an innovative fracture network reservoir simulator is proposed to monitor and manage the aquifer's role in pressure maintenance and water production. The new fracture simulation model will be used for both planning optimal paths for new wells and improving ultimate recovery.

In the second phase of this project, the model will be used for the design of a pilot program for downhole water re-injection into the aquifer simultaneously with oil production. Downhole water separation units attached to electric submersible pumps will be used to minimize surface fluid handling thereby improving recoveries per well and field economics while maintaining aquifer support.

In cooperation with the DOE, results of the field studies as well as the new models developed and the fracture database will be shared with other operators. Numerous fields producing from the Monterey and analogous fractured reservoirs both onshore and offshore will benefit from the methodologies developed in this project.

This report presents a summary of all technical work conducted during the fifth quarter of Budget Period I.

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Introduction

The Field Demonstration site for this Class III (basin clastic) Program Proposal is the South Ellwood Field located offshore California. The Monterey Formation is the main producing unit in the South Ellwood Field and consists of fractured chert, porcelanite, dolomite, and siliceous limestone interbedded with organic mudstone. This reservoir has an average thickness of 1,000 feet, and lies at subsea depths of approximately -3,500' to -5,000'.

Venoco and USC jointly submitted an application to conduct a DOE co-operative investigation of the Monterey formation at South Ellwood in June 2000. The DOE granted this application in July 2000.

Executive Summary

Venoco and USC prepared a proposal for a DOE sponsored joint investigation of the fractured Monterey formation. It was agreed that Venoco would construct the geologic model for the field and gather new reservoir data as appropriate. USC would then develop a simulation model that would be used to optimize future hydrocarbon recovery. Joint Venoco-USC teams were established to manage the flow of data and insure that Venoco and USC activities remained synchronized. A co-operative agreement was signed with the DOE on July 31, 2000.

This cooperative work between the research team at USC and the engineers and geoscientists at Venoco has generated new insights into formation evaluation methods for the Monterey Formation, has resulted in the formulation of new approaches to describe reservoir dynamics and to simulate reservoir performance. Major accomplishments for the project so far are development of an interactive database on the Monterey Formation, a conceptual model for description of fractured controlled Monterey Reservoirs and methods for recognition of fractured producing intervals.

The Web base data archives of the South Ellwood field will be a subject of a presentation scheduled for the Western Regional Meeting of SPE in Anchorage Alaska during the last week of May 2002. Meanwhile, efforts are continuing to allow the Web site to generate interactive reports. The site will serve as a premier compact reference library for specific aspects of the project as well as general observations about the Monterey Formation.

The major focus during this reporting period was on export of the geological model into the simulation model. New tasks to track the movement of the oil-water contact through time and detect entry of seawater into the reservoir were started. The fracture identification study continued and several zones for re-completion have been identified using the pattern recognition techniques developed earlier.

Task I-Database

The Web based database was updated with additional information and a search module was added for convenient location of important information.

Task II: New Data

New static pressure data were obtained during the platform shut down in December 2001. Quartz pressure gauges were hung in five wells 3120-12, 3242-13, 3242-19, 3242-18 and 3272-7-1 and remained in the hole during a 10 day platform shutdown. Reservoir pressure is similar to the values measured in March 2001 i.e. 1300 psi. There is a slight pressure gradient of 40 psi between the most Westerly well 3120-12 and the most Easterly producer 3242-18. This data supports the idea that fluid is influxing from the lease extension area to the East. This information is of significant importance for history match studies.

Task III: Basic Reservoir Studies

Detection of By-Passed Intervals

The pattern recognition developed earlier ideally requires the following well log signals:

1. Gamma Ray (GR)
2. Neutron Porosity (NP)
3. Density Porosity (DP)
4. Sonic Travel Time (ST)
5. Resistivity Ratio (RR)
6. Caliper (CL)

Three Lithology types indicative of producing potential have been identified based on characteristic radar plots using the six log signals listed above. The three lithology types identified are:

Type A - fractured and/or brecciated intervals.
Type B - dolomitic intervals.
Type C - granular type sandstone layers.

Note: Identification Type B and C indicators have been grouped as Type B/C to expedite log review.

Well Log data set for two wells (wells 3120-16 and 3242-12) were selected to test the concept of pattern recognition method developed earlier in this project. Each well had a recent production survey run using Schlumberger's GHOST tool to accurately identify fluid entry. Each dataset was then reviewed to compare occurrences of the IWPP indicator with the actual producing, perforated zones in the well. Figure 1 shows a section of a calibration Log for 3120-16 with the lithology signal indicators noted in the lithology track of the log. The Type A signal appears in the perforated zone (depth 7390' to 7420') where fluid entry is identified by the GHOST tool (Track QOC Calc. of Log 3120-16). Additionally, Type A indicators are also found in unperforated zones of the well indicating bypassed intervals with production potential (IWPP).

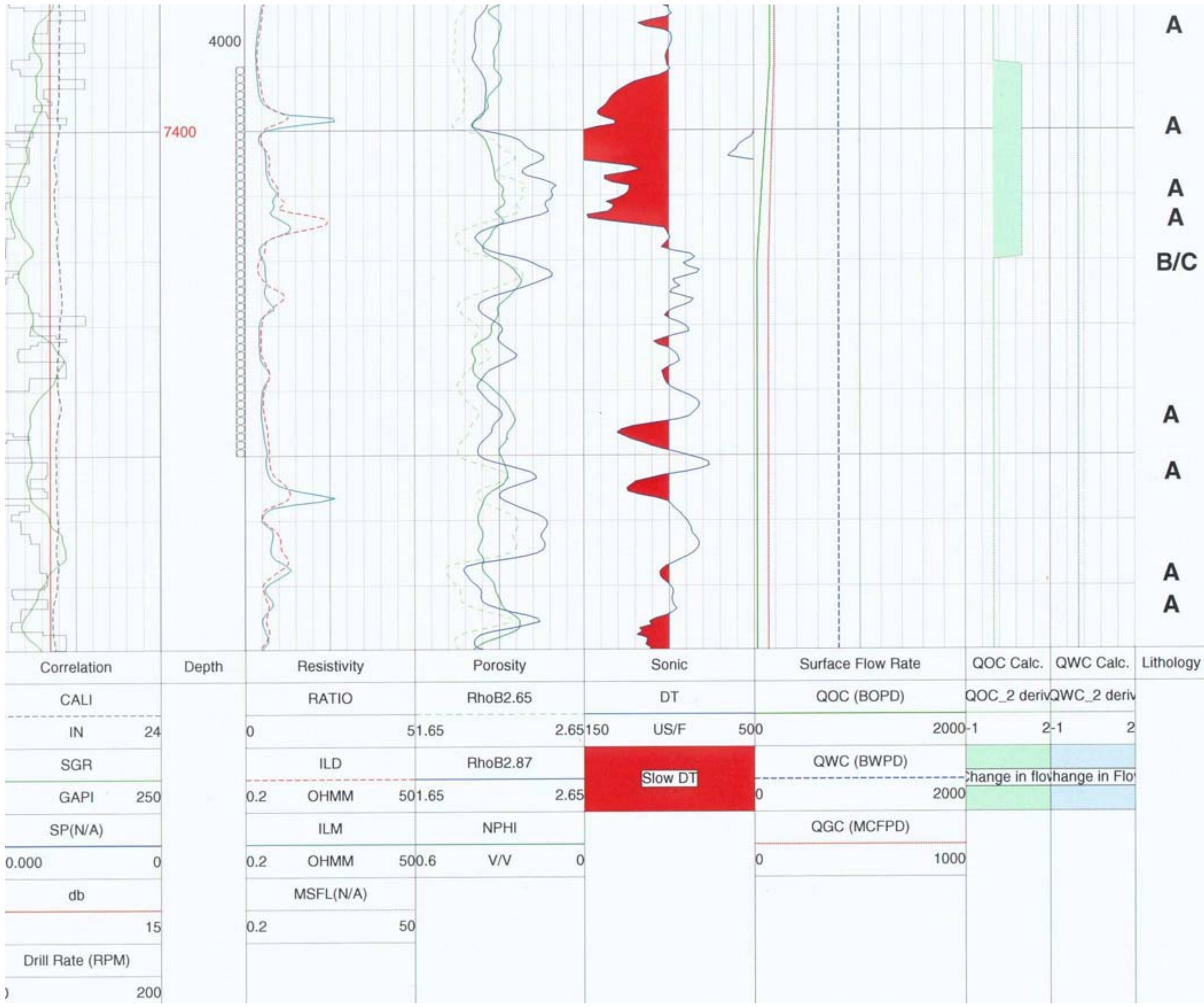

Figure 1. Composite Computed Log for South Elwood Well 3242-16 (section from 7380' to 7480')
IWPP noted in the Lithology Track.

Well logs from twelve wells from the South Ellwood Field were then reviewed to identify formation lithology and intervals with production potential (IWPP).

The South Ellwood wells reviewed thus far are listed in Table I.

Well	Well Type	Complete Signal Suite
3120-03	Data	No - NP,DP,ST,RR,CL
3120-11	Data	No - GR,NP,DP,ST,
3120-15D1	Data	Yes - GR,NP,DP,ST,RR,CL
3120-15D2	Data	Yes - GR,NP,DP,ST,RR,CL
3120-16	Calibration/Data	Yes - GR,NP,DP,ST,RR,CL
3242-08RD4	Data	Yes - GR,NP,DP,ST,RR,CL
3242-10D1	Data	Yes - GR,NP,DP,ST,RR,CL
3242-12	Calibration/Data	No - GR,NP,RR,CL
3242-14	Data	Yes - GR,NP,DP,ST,RR,CL
3242-15	Data	Yes - GR,NP,DP,ST,RR,CL
3242-16	Data	Yes - GR,NP,DP,ST,RR,CL
3242-17	Data	Yes - GR,NP,DP,ST,RR,CL

Table 1. Log signal availability for twelve South Ellwood Wells

Additional South Ellwood wells are being reviewed for application of this technique. Wells with the required signals will be identified.

Table 2 shows a summary of unperforated intervals with potential for production.

Table 2- List of Potential Unperforated Intervals in some of the South Elwood Wells.

Well 3120-16		Well 3242-12		Well 3242-15		Well 3120-03		Well 3120-15D1		Well 3242-08RD4		Well 3242-17		Well 3242-16		Well 3120-15D2		Well 3242-10D1		Well 3120-11		Well 3242-14	
Depth	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**
6815P	A	5258	B/C	**5235**	**A**	3973	B/C	4655	B/C	3850	A	4446	B/C	4500	B/C	5470	A	3605	B/C	6007		4348	B/C
6828P	A	5315	B/C	5257	A	4003	A	4662	B/C	4008	B/C	4484	B/C	4618	B/C	5475	B/C	3612	B/C	6198	B/C	4440	B/C
6855	A	5345	N/A	5662	A	4013	A	4678	B/C	4038	C/D	4505	B/C	4697	A	5480	B/C	3632	B/C	6228	B/C	4527	B/C
6912P	A	5385	N/A	5305	A	4031	A	4763	B/C	4053	A	4536	A	4705	A	5496	B/C	3636	B/C	6251	B/C	4670	A
6923P	A	5445P,t	A	**5312**	**A**	4052	A	4775	B/C	4064	D	4887	A	5337	A	5999	B/C	3637	B/C	6258	HS	4677	A
6938P	A	5478P,t	A	5317	B/C	4062	B/C	4828	B/C	4095	A	4925	A	5383	A	5501	B/C	3641.5	B/C	6264	B/C	4853	A
6968P	B/C	5495P	B/C	5403	A	4071	A	4867	B/C	4115	A	5046	A	5343	A	5508	B/C	3646	A	6353	B/C	4956	A
6978P	A	5505	B/C	5412	B/C	4085	B/C	5045	F?	4250	A	5198	B/C	5892	A	5513	B/C	3651.5	B/C	6380	B/C	4976	A
6988P	B/C	5564P	B/C	5422	B/C	4108	B/C	5158	B/C	4262	A	5220	A	5914	B/C	5520	B/C	3658	B/C	6410	B/C	5146	A
7014	A	5579P	A	5460	A	4131	A	5308	B/C	4292	B/C	5305	A	5945	B/C	5528	B/C	3661.5	B/C	6418	A	5173	A
7035	B/C	5649P	B/C	5470	B/C	4139	A	5328	B/C	4335	B/C	5462	A	5985	B/C	5541	B/C	3665	B/C	6425	A	5188	B/C
7053	B/C	5671P,t	A	5505	B/C	4157	B/C	5340	B/C	4382	A	5497	A	6010	A	5551	B/C	3673	B/C	6438	A	5217	B/C
7070	A	5713P	B/C	5542	B/C	4190	A	5370	B/C	4463	A	5528	B/C	6015	B/C	5558	B/C	3680	B/C	6498	A	5308	B/C
7090P	A	5723P	B/C	5581	B/C	4208	A	5385	B/C	4808	B/C	5554	A	6020	A	5591	A	3690	B/C	6725	A	5322	A
7113P	A	5758P	B/C	5587	B/C	4233	B/C	5433	B/C	4850	B/C	5605	A	6195	A	5641	B/C	3700	B/C	6737	A	5334	B/C
7127P	A	5830	B/C	5621	A	4253	A	5482	B/C	4945	D	5612	A	6340	B/C	5645	B/C	3707	B/C	6740	A	5387	A
7138P	A	5846P	B/C	5630	B/C	4272	B/C	5509	B/C	4969	B/C	5635	B/C	6418	A	5677	B/C	3717	A	6940	A	5409	A
7153P	B/C	5872P	A	5637	B/C	4283	A	5611	B/C	5208	A	5673	B/C	6436	B/C	5688	A	3754	B/C	6953	A	5433	A
7159P	A	5912P	B/C	5642	B/C			5632	B/C	5359	A	5685	A	6515	A	5698	B/C	3764	B/C	7005	B/C	5689	A
7172P	A	5936P	B/C	5652	B/C			5665	B/C	5390	A	5737	A	6655	B/C	6116	B/C	3769	B/C	7018	A	5754	A
7187P	A	5956	B/C	**5685**	**A**			5677	B/C	5410	A	5790	B/C	6870	B/C	6120	B/C	3775	B/C	7023	A	5793	B/C
7195P	A	5982	B/C	5710	A			5694	B/C	5439	B/C	5803	A	6915	B/C	6131	B/C	3777	B/C	7029	A	5834	B/C
7208P	A	6002	B/C	**5718**	**A**			5704	?	5459	B/C	5832	A	6935	B/C	6156	B/C	3779	B/C	7098	A	5852	B/C
7215P	A	6023	B/C	**5770**	**A**			5721	B/C	5482	B/C					6206	B/C	3785	B/C	7127	A	5857.5	B/C
7227P	A	6052P	A	5838	A			5762	B/C	5528	B/C					6212	B/C	3788	B/C	7430	B/C	5876	B/C
7237P	A	6072P	A	5843	A			5777	B/C	5592	B/C					6227	B/C	3795	A	7466	A	5894	A
7242P	A	6085P	A	6113	A			5792	B/C	5619	B/C					6252	B/C	3798	B/C	7520	A	5899	A,C

Well 3120-16		Well 3242-12		Well 3242-15		Well 3120-03		Well 3120-15D1		Well 3242-08RD4		Well 3242-17		Well 3242-16		Well 3120-15D2		Well 3242-10D1		Well 3120-11		Well 3242-14	
Depth	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**	**Depth**	**Lith. Type**
7258P	B/C	6102	A	6132	A			5808	B/C							6261	SH	3805	A	7536	B/C	5909	B/C
7268P	A	6115	A	6150	A			5834	B/C							6278	A?	3813	A	7566	A		
7295P	A	6129	A	6157	B/C			5840	B/C							6288	SH?	3816	B/C	7613	A		
7305P	A	6138	A	6216	A			5851	B/C							6303	B/C	3820	B/C	7638	A		
7317P	B/C	6162	A	6220	A			5898	B/C							6310	B/C	3826	B/C	7668	B/C		
7320P	A	6178P	B/C	6227	A			5921	B/C							6327	B/C	3831	B/C	7698	B/C		
7340P	A	6200P,t	A	6315	B/C			5982	B/C							6333	B/C	3838	B/C	7715	B/C		
7355	B/C	6224P	B/C	6461	A			6005	B/C							6344	A	3845	B/C	7727	B/C		
7370	B/C	6240P		6428	A			6028	B/C							6348	A	3971.5	B/C	7740	A		
7385	A	6246P	A	**6485**	**A**			6039	B/C							6367	B/C	3974.5	B/C	7745	A		
7403P	A	6275P	B/C	**6487**	**A**			6054	B/C							6375	B/C	3983	B/C	7759	B/C		
7411P	A	6309	B/C	6708	A			6093	B/C							6382	A	3994	B/C	7769	A		
7415P	A	6335	A	**6718**	**A**			6150	B/C							6400	B/C	4001	B/C	7789	B/C		
7422P	B/C	6348	A	6735	A			6205	B/C							6418	A	4022	A				
7446P	A	6405	B/C	6855	A			6250	B/C							6444	B/C	4223	B/C				
7455	A	6486	B/C	6867	A			6272	B/C							6451	SH?	4228	A				
7470	A	6510P	A	7104	B/C			6317	B/C							6458	B/C	4233	B/C				
7475	A	6545	A	7148	B/C			6345	B/C							6489	A	4243	A				
7490P	A	6570	A	7289	A			6385	B/C							6492	B/C	4238	B/C				
7525P	D	6610P	A	7301	A			6404	B/C							6507	B/C	4250	A				
7532P	B/C	6643P	A	**7318**	**A**			6450	B/C							6518	B/C	4261	B/C				
7560P	A			7398	B/C			6474	B/C							6556	B/C	4268	B/C				
7587P	B/C			7525	A			6505	B/C							6558	B/C	4273	B/C				
7595P	B/C			7538	B/C			6547	B/C							6580	B/C	4278	A				
7608P	A			7558	A			6586	B/C							6595.5	B/C	4382	A				
7617P	A			7572	B/C			6614	B/C							6610	B/C	4391.5	B/C				
7630P	A			7595	B/C											6627	B/C	4398.5	B/C				
7643P	A			7675	A											6640	B/C	4403	A				

Well 3120-16		Well 3242-12		Well 3242-15		Well 3120-03		Well 3120-15D1		Well 3242-08RD4		Well 3242-17		Well 3242-16		Well 3120-15D2		Well 3242-10D1		Well 3120-11		Well 3242-14	
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7668	B/C			7735	A											6700	B/C	4470	A				
7675	B/C			7750	A											6712	B/C	4475	B/C				
7688	B/C															6737	B/C	4478	A				
7702P	A															6740	B/C	4488	A				
7712P	A															6770	B/C	4494	?				
7722P	A															6805	B/C	4500	B/C				
7785P	A															6746	?	4593	B/C				
7795P	A															6754	B/C	4605	A				
7815P	A															6891	B/C	4608	B/C				
7840P	A															6925	A	4634	A				
7855P	A															6940	A	4637	A				
7870	A															6951	B/C	4666	A				
7883	A															6962	B/C	4770	B/C				
7942P	A															6970	?	4787	B/C				
7982P	A															6988	B/C	4695	B/C				
8010P	A															6990	?	4810	B/C				
																7005	A	4818	?				
																7017	A	4876	B/C				
																7100	B/C	4886	B/C				

Fluid Entry Surveys and Monitoring of Oil Water Contact

An important parameter in the history matching of the South Ellwood simulation model is movement of the OWC as interpreted from production logs. The following is a list of the survey data thus far located in the archives. Efforts are continuing to locate additional surveys and to post them on the database.

Fluid Entry Surveys were obtained for the following wells:

3120-3-1	8/9/93
3120-3-1	1/17/90
3120-3-1	4/11/86
3120-3-1	3/12/86
3120-7-3	8/6/93
3120-9-1	8/2/93
3120-10	3/26/88
3120-10	4/15/86
3120-12	8/13/93
3120-13	8/5/93
3120-16	3/23/88
3120-3-12	4/14/86
3242-5	1/19/90
3242-8-4	7/26/93
3242-10-1	7/21/93
3242-10-1	1/20/90
3242-13	7/22/93
3242-15	7/22/93
3242-16	8/4/93
3242-16	11/10/85
3242-19	8/12/93

Sea Water Intrusion Study

We started a study comparing the geochemical composition of the reservoir water with seawater.

- Prepared a dataset of 28 different analysis of chemical composition of produced water for the wells producing from South Ellwood Monterey formation and 2 sea water composition analysis.
- Initiated generation of Stiff diagrams through the use of Hydrochem software.

The following list shows a summary of the available water chemical composition analysis data:

SW-1 (2-14-94), sea water
SW-2 (2-14-94), sea water
3120-3 (11-17-98)
3242-7 (11-5-85)
3242-7 (11-23-85)
3242-7 (1-4-86)
3242-7(1-6-86)
3120-7(8-10-94)
3120-8 (4-11-77)
3120-8 (8-17-77)
3120-8 (2-14-74)
3120-8 (7-11-94)
3242-9 (11-13-79)
3242-10 (10-9-77)
3242-10 (11-4-77)
3242-10 (10-20-77)
3242-10 (10-28-77)
3120-11 (9-11-79)
3120-11 (1-12-79)
3120-11 (8-17-94)
3242-12(date not available)
3242-13 (1-12-79)
3120-14 (5-17-78)
3120-15 (8-19-80)
3120-15 (10-28-81)
3242-16(2-14-94)-1
3242-16(2-14-94)-2
3242-19 (9-13-85)
3242 Group Sample (7-11-01)
3120 Group Sample (8-10-01)

Simulation Studies

Pipeline Model:

For the pipeline model, efforts were focused on re-compiling the 2-D model for a larger number of cells for comparison with the CMG model. Initial steps were taken to expand the formulation to 3D 2 phase.

CMG Model:

To speed up the major simulation study of the South Ellwood using the CMG model, a great deal of efforts was focused on grid generation and assignment of conceptual model.

- The primary geological model to be built is based on three constant layers of formation and the new horizon top and fault system data (excluding any minor inner faults,(see Figure 2) conceptualized by the Venoco geologic model.

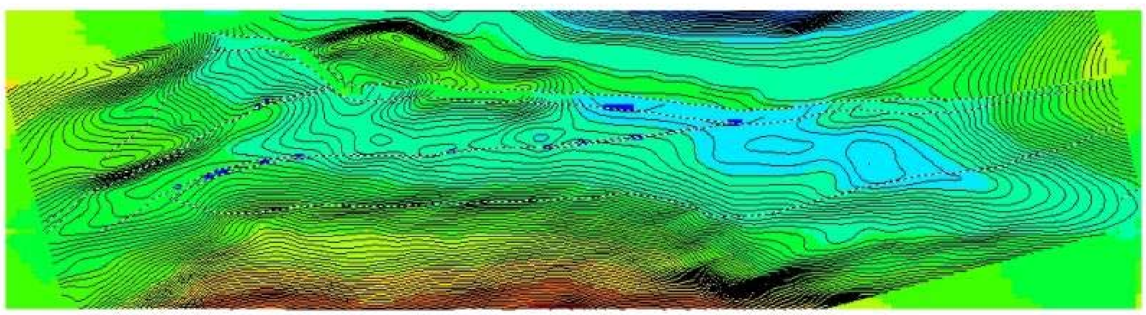

Figure 2: Tentative 2-D image of formation top

- The simulation is approach is planned to allow flexibility for future changes to the nature of inner faults/fractures/micro-fractures systems.
- The major fault (Figure 3) to the north will be considered a sealing fault and an aquifer will be attached to the south flank at a depth of 4300 ft.

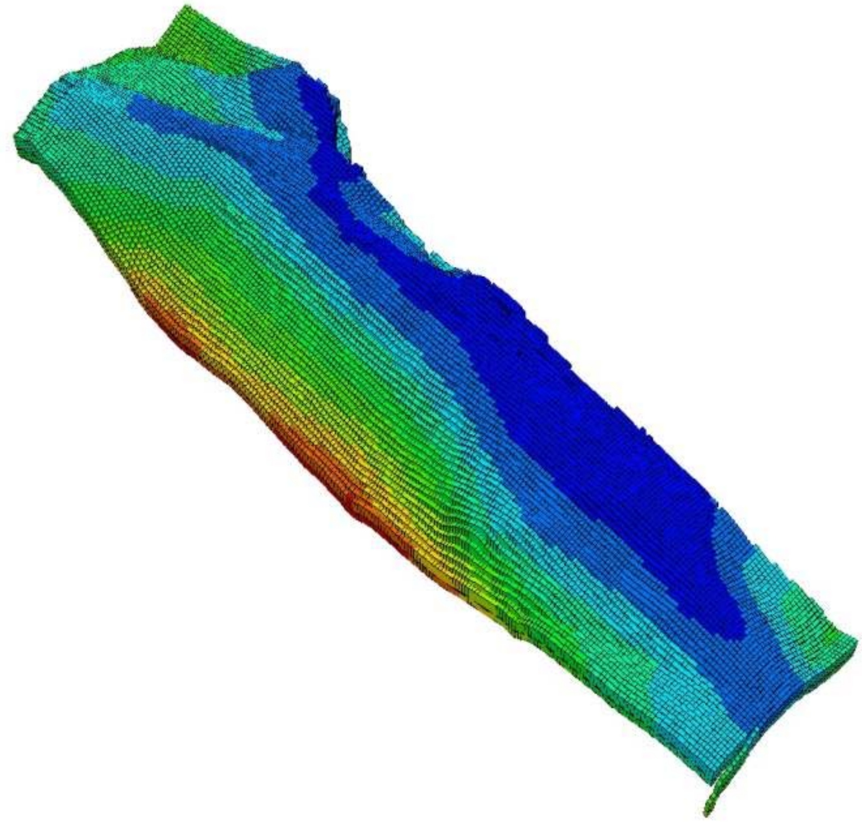

Figure 3: Tentative 3-D image of formation top

- prepared a complete set of perforation data for leases 3120 and 3242
- Started preparing perforation history dataset in IMEX compatible format.
- Started preparing production datasets in an IMEX compatible format.
- Prepared final version of well trajectory dataset

Modeling Concepts:
In the preparation of the CMG dataset for the proposed simulation model, the following were taken into consideration:

1. Flexibility in the gridding process to add sub faults for history matching purposes.
2. Implementation of exact well trajectories ranging from vertical to highly deviated single laterals
3. Data from well 3120-8 at 3570 feet MD is used and adjusted to obtain representative curves of oil formation volume factor, solution gas ratio, and oil viscosity at the particular API gravity value. Based on the field observations, the API gravity varied from a minimum of 15 to a maximum of 32. Therefore, these two values formed the basis for the upper and lower API gravity tables used in the model. An intermediate API gravity is generated, based on the trends observed from the samples, in order to improve model stability.
4. The properties of the gas are assumed to be constant throughout the field.
5. Initial relative permeability sets for fractured systems will be obtained from production data.
6. There are no laboratory analyses of core samples from which the gas/oil relative permeability behavior could be measured. A synthetic normalized curve that best models the field behavior is used. The critical gas saturation is set to zero allowing gas to flow immediately from the grid cell based on the cell's saturation. The endpoints values are as follows:
   Critical gas saturation=0.0
   Residual oil saturation (with respect to gas)=0.30
   Relative permeability of oil to gas at minimum gas saturation=0.70
   Relative permeability of gas at residual oil saturation=0.15
7. Because the bulk of the majority of the production is from the fracture system, capillary pressure is assumed to be zero throughout all saturation ranges.
8. In general, most of the wells in the South Ellwood field are high angle or close to horizontal, while a few, near platform Holly, are nearly vertical. The horizontal completion can range from 1000 feet to over 4000 feet in length. Most wells currently have completions or have had completions in all seven layers of Monterey horizons. Most wells have been re-completed several times, with many zones being added, re-perforated, or plugged-back through the course of history.
9. The South Ellwood field does not have any significant stratigraphic barriers or structural faults to compartmentalize the field into separate blocks. A sloping/sealing fault on the north side of the field is incorporated to model

the northern boundary of the field structure. A Cartesian gridding scheme is selected, resulting in a grid dimensioned by 228 cells in the x-direction and 60 cells in the y-direction. Each grid cell's dimensions are approximately 200.feet long by 200 feet wide (Figure 4).

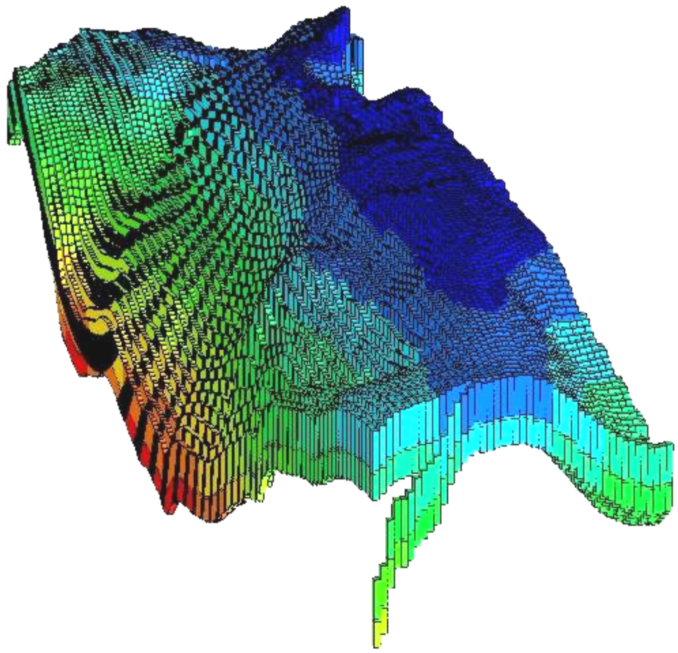

Figure 4: Tentative 3-D image of formation, showing areal gridding and three constant layers(looking from the east)

Task IV--Stimulation

None

Task V- Project Management

Project review meetings were held on a monthly basis in Carpinteria. Progress reports from various individuals were reviewed. Individuals working on the project during this quarter included:

Database:
Katie Boerger (USC), Kim Halbert (Venoco) and Tim Rathmann (Venoco), Chris Knight (Venoco), I. Ershaghi (USC), H. Patel (USC)

Reservoir Studies:
I. Ershaghi (USC), Lang Zhang (USC), A. Zahedi (USC), Anthony Taglieri (USC), Steve Horner (Venoco), M. Heidari (USC), M. Kashfi (USC), Z. Yang (USC).

Geological Modeling
Mike Wracher (Venoco), Karen Christensen (Venoco)

Geophysical Modeling
Karen Christensen (Venoco)

Project Management:
Steve Horner (Venoco) and I. Ershaghi (USC)

Technical Support:
Chris Knight (Venoco) and Tim Rathmann (Venoco)

Task VI: Technology Transfer

Three abstracts were submitted for the Western Regional Meeting of SPE and all three have been accepted for presentation scheduled for May , 2002 in Anchorage Alaska.

Conclusions

During this reporting period, we moved one step closer to integrating all data sets into the simulation model for prediction purposes. Because of the particular geometry of fractured system we will be implementing, we faced some difficulties in the gridding process. But many of the obstacles have been resolved and we expect initiation of the history match to commence during the next reporting period. Additionally a number of support activities were started to gain additional insight into the dynamics of the South Ellwood reservoirs. Among these we started a new effort in incorporating water chemistry data as well as fluid entry surveys.