

**INCREASED OIL PRODUCTION AND RESERVES UTILIZING  
SECONDARY/TERTIARY RECOVERY TECHNIQUES ON SMALL RESERVOIRS IN  
THE PARADOX BASIN, UTAH**

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# **INCREASED OIL PRODUCTION AND RESERVES UTILIZING SECONDARY/TERTIARY RECOVERY TECHNIQUES ON SMALL RESERVOIRS IN THE PARADOX BASIN, UTAH**

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## **Objectives**

The primary objective of this project is to enhance domestic petroleum production by demonstration and technology transfer of an advanced oil recovery technology in the Paradox basin, southeastern Utah. If this project can demonstrate technical and economic feasibility, the technique can be applied to approximately 100 additional small fields in the Paradox basin alone, and result in increased recovery of 150 to 200 million barrels of oil. This project is designed to characterize five shallow-shelf carbonate reservoirs in the Pennsylvanian (Desmoinesian) Paradox Formation and choose the best candidate for a pilot demonstration project for either a waterflood or carbon dioxide- (CO<sub>2</sub>-) flood project. The field demonstration, monitoring of field performance, and associated validation activities will take place in the Paradox basin within the Navajo Nation. The results of this project will be transferred to industry and other researchers through a petroleum extension service, creation of digital databases for distribution, technical workshops and seminars, field trips, technical presentations at national and regional professional meetings, and publication in newsletters and various technical or trade journals.

## Summary of Technical Progress

Three activities continued this quarter as part of the geological and reservoir characterization of productive carbonate buildups in the Paradox basin: (1) delineating a potential calcarenite trend which includes the Heron North field (Fig. 1), (2) reservoir characterization of Runway field (Fig. 1), and (3) technology transfer.

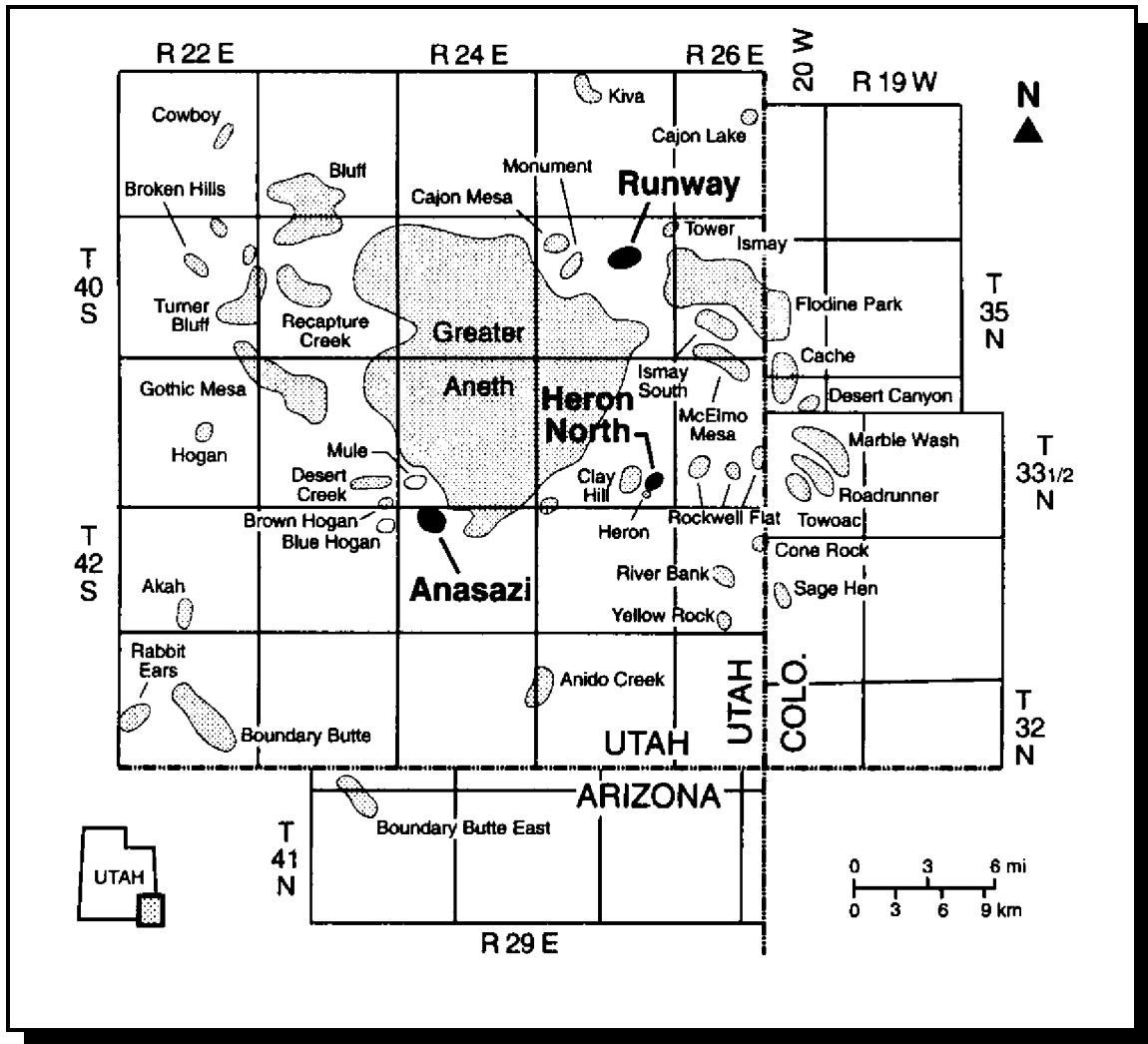
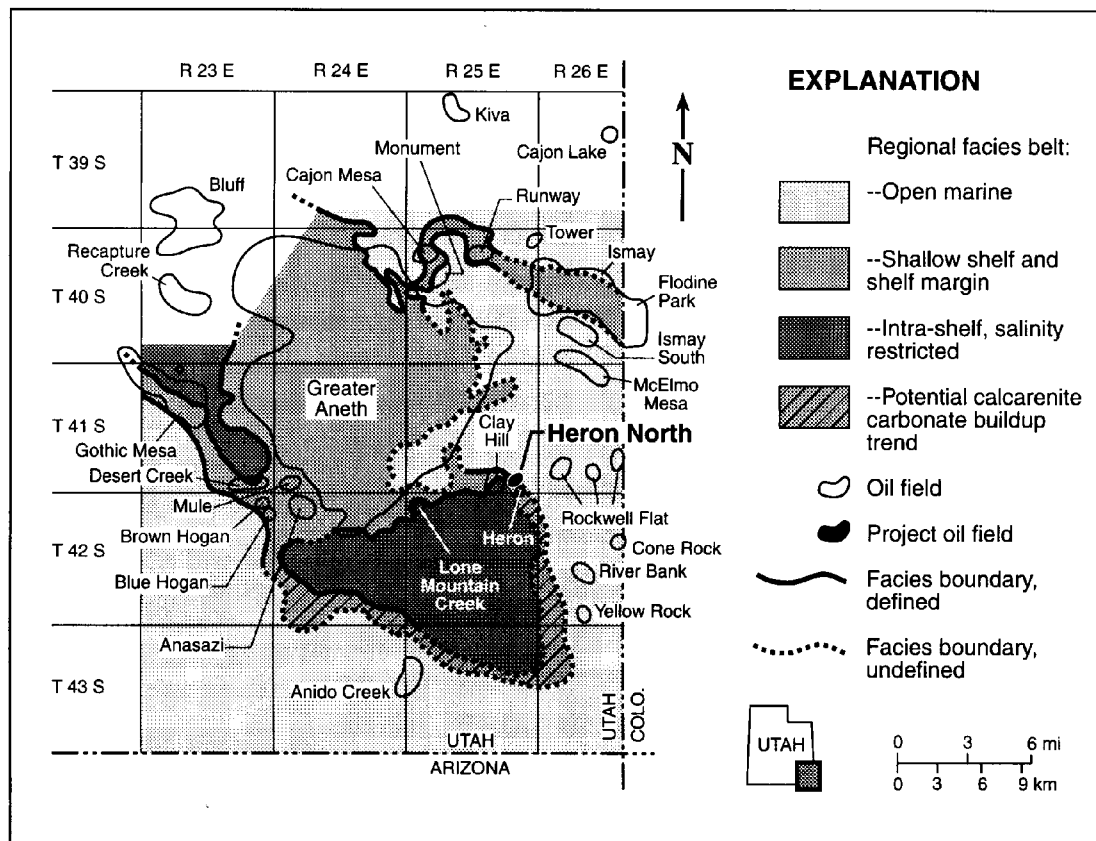


Fig. 1. Location of Heron North, Runway, and Anasazi fields (dark shaded areas with names in bold type) in the southwestern Paradox basin on the Navajo Nation, San Juan Co., Utah.

### *Potential Calcarenite Trend*

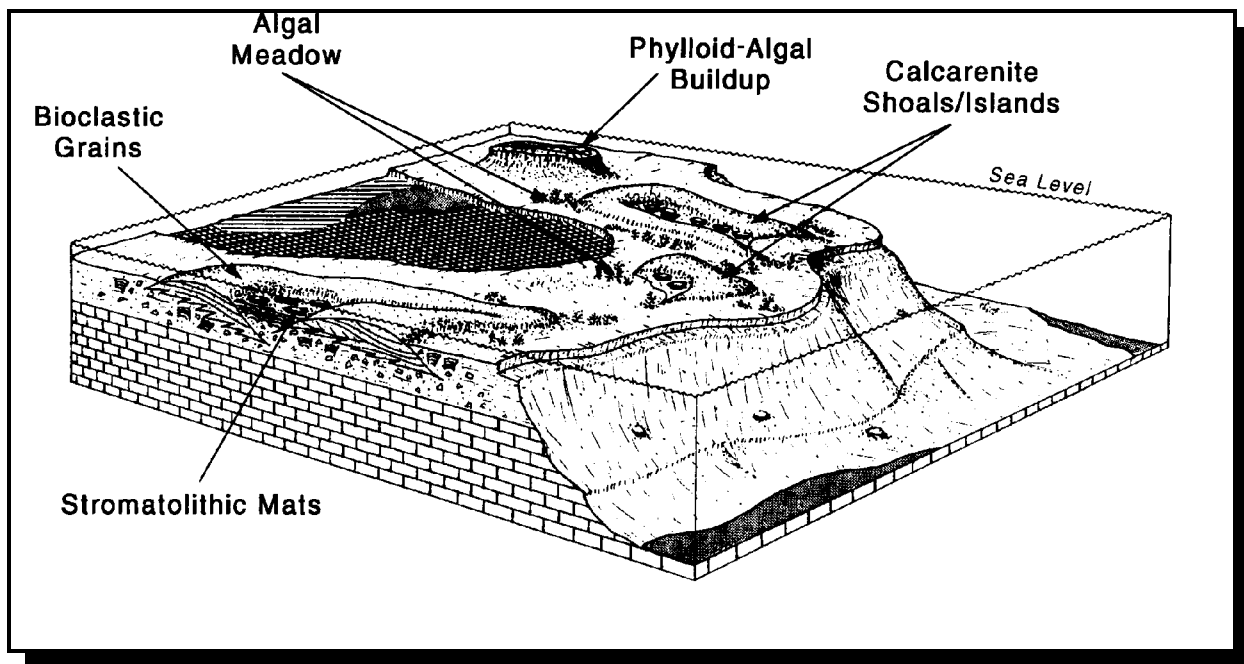
Mapping of the regional lithofacies of the Desert Creek zone of the Paradox Formation indicates a relatively untested belt of shallow-shelf, calcarenite carbonate deposits (Fig. 2). This narrow but long belt of calcarenite lithofacies is between open marine lithofacies and the margins



**Fig. 2. Regional facies belts of the Desert Creek zone, Paradox Formation, and potential calcarenite buildup trend, Navajo Nation, southeastern Utah.**

of intra-shelf, salinity-restricted lithofacies. Calcarenite buildups represent high-energy environments where shoals and/or islands developed as a result of regularly agitated, shallow-marine processes on the shelf (Fig. 3). Characteristic features of this lithofacies include medium-scale cross bedding and bar-type carbonate sand-body morphologies and algal meadows. Sediment deposition and modification probably occurred from 5 ft above mean sea level to 20 ft below sea level.<sup>1</sup>

Heron North field (Fig. 1), one of five project fields, is an excellent example of the type of fields which potentially lie within this 20-mi-long lithofacies belt. The field consists of one well, the North Heron No. 35-C, completed in 1991 at an initial potential flow of 605 bbls of oil per day and 230 MCFGPD. The field is a lenticular, northwest- to southeast-trending linear mound/beach complex, 0.8 mi long and 0.5 mi wide.<sup>2</sup> The reservoir consists of five units: (1) a basal, dolomitized phylloid algal (bafflestone) buildup, (2) a limestone, anhydrite-plugged phylloid algal (bafflestone) buildup, (3) a fusulinid-bearing, lime-wackestone interval, (4) a dolomitized packstone interval with anhydrite nodules, and (5) a porous (15%), sucrosic, dolomitized grainstone and packstone interval, the main reservoir, consisting of alternating 2- to 4-ft-thick packages of uniform beach calcarenite and poorly sorted foreshore and storm-lag rudstone or breccia deposits.



**Fig. 3. Depositional environments of the calcarenite facies along the narrow shelf margin between the open-marine and intra-shelf, salinity-restricted facies belts.**

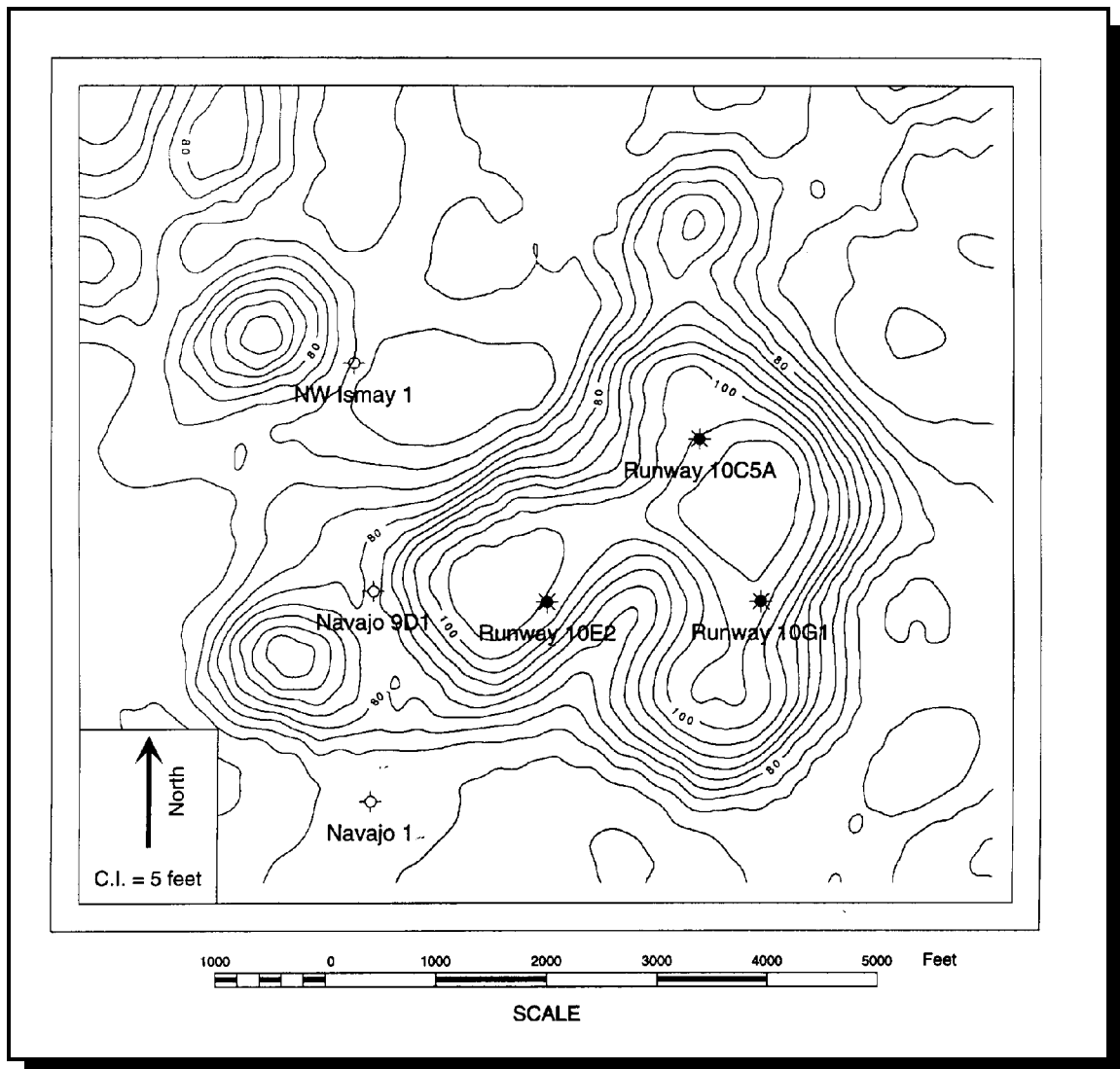
Cumulative production from Heron North field is 206,446 bbls of oil (BO) and 0.33 billion cubic feet of gas (BCFG) as of July 1, 1997.<sup>3</sup> Estimated primary recovery from the field and others that are likely along the trend is 990,000 BO and 2.65 BCFG. These types of traps have both negative and positive characteristics for hydrocarbon production. Negative characteristics include: (1) small reservoir size and storage capacity, (2) difficult to identify on seismic records, (3) limited distribution, (4) bitumen plugging is common, and (5) rapid production declines. Positive characteristics include: (1) excellent overall reservoir properties, (2) associated with phylloid algal buildups, (3) candidates for water/CO<sub>2</sub> floods, and (4) located on an extensive untested trend.

### ***Reservoir Characterization of Runway Field***

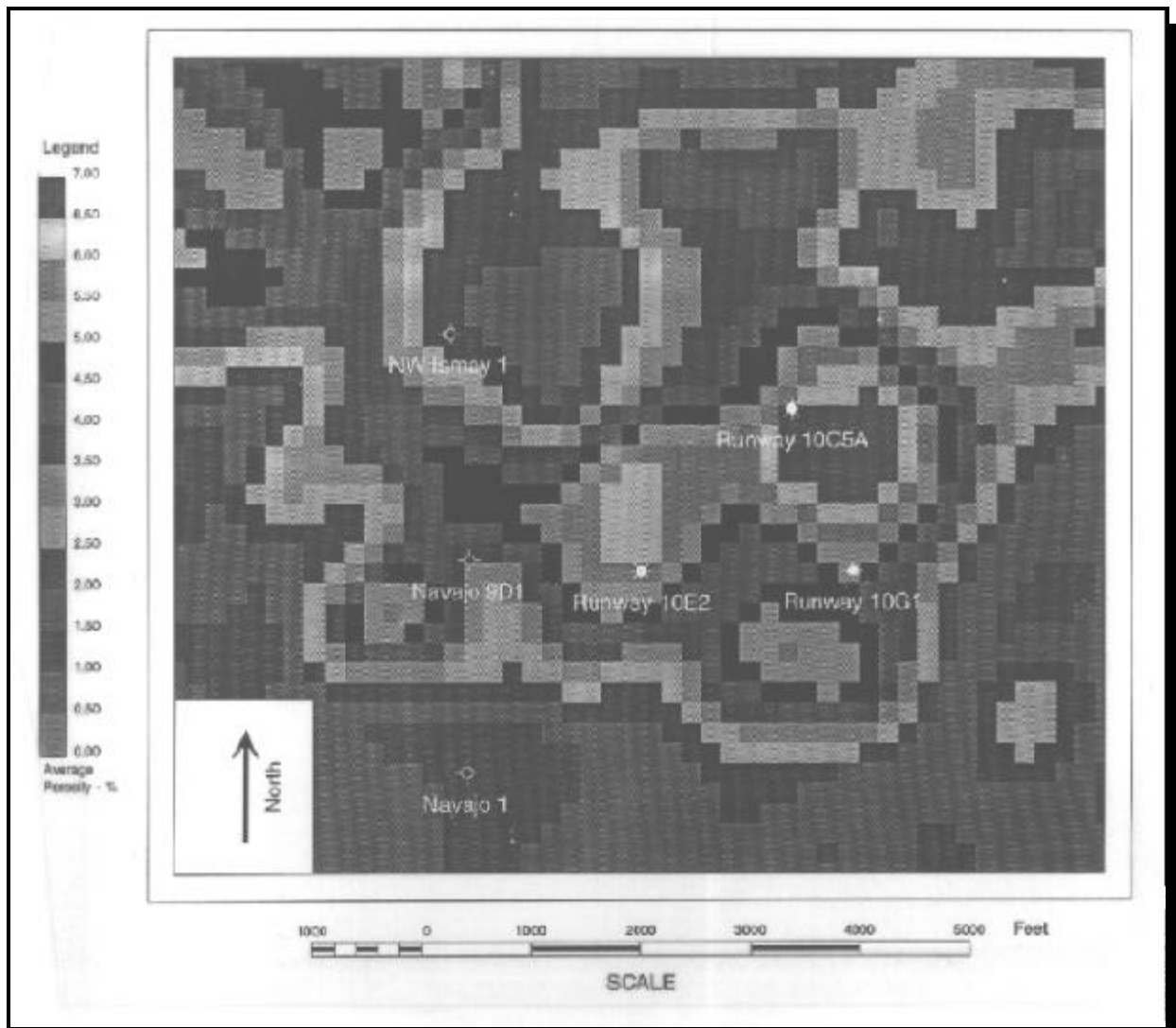
The two main work tasks for Runway field (Fig. 1) during the quarter were: (1) quantitative characterization of the Runway carbonate-mound buildup reservoir, and (2) initiation of two-dimensional mechanistic flow simulation studies. History matching using the complete three-dimensional reservoir model will commence next quarter.

The Desert Creek carbonate-mound buildup reservoir at Runway field was selected for a follow-up study to the recently completed Anasazi field (Fig. 1) reservoir assessment both for comparison with those results, and also as a more promising candidate for a Phase II pilot demonstration due to the closer proximity of Runway to potential sources of injectable CO<sub>2</sub>. Runway field is somewhat larger (193 ac) than Anasazi (165 ac) with a thicker average net pay (72 ft and 57 ft, respectively) but lower average net pay porosity (11.9% and 14.1%, respectively).<sup>4,5</sup> As of July 1, 1997 the three Runway producing wells had seven-year cumulative hydrocarbon production of 780,272 BO and 2.51 BCFG.<sup>3</sup> Three additional dry holes previously drilled nearby have provided off-mound thickness, lithology, and porosity data.

Although three-dimensional seismic data have not been acquired over Runway field, two sets of closely spaced swath lines have provided the data for defining the geometry and average porosity of the Desert Creek carbonate mound reservoir with greater confidence than was possible at Anasazi. The carbonate-mound buildup isolith map (Fig. 4) was obtained by time-depth conversion on the top and base of the Desert Creek zone, tied to the three Runway wells plus six other wells in the vicinity. The thickness of the smoothly varying anhydrite at the top of the Desert Creek was subtracted to produce the carbonate reservoir isolith map. Average porosity (Fig. 5) was obtained from the seismic amplitude data. The porosity grid was also tied to the wells used in the isolith map and thickness effects were deleted. Figures 4 and 5 clearly depict the Runway carbonate-mound buildup, with the best reservoir quality (as represented by average porosity) closely corresponding to the buildup areas.



**Fig. 4. Carbonate isolith map of the Desert Creek reservoir, Runway field.**



**Fig. 5. Average porosity grid of the Desert Creek reservoir, Runway field.**

The three-fold subdivision of the Anasazi carbonate-mound buildup into platform, mound-core, and supra-mound intervals is also present at Runway, although the carbonate lithotypes are somewhat different. At least three distinct mound-building episodes by phylloid algae, followed by fenestrate bryozoa, and phylloid algae again, are represented in the Runway reservoir. Primary carbonate stratigraphy is less heterogeneous at Runway than at Anasazi, although the supra-mound interval in the thickest parts of the mound has undergone a great deal of secondary solution collapse brecciation, as seen in core from the Runway No. 10-E-2 well.

The Runway reservoir model consists of a 1,548-block areal grid (43 columns, 36 rows), with each square grid block measuring 180 ft on a side. As at Anasazi, the Desert Creek carbonate interval was subdivided into 50 equal-thickness layers, ranging from 1.3 ft thick in the offmound areas to 2.3 ft in the thickest part of the mound.<sup>6</sup> Because one well (Runway No. 10-G-1) also produces from the upper Ismay zone of the Paradox Formation, two additional layers are included in the model, one 60-ft layer for the Ismay carbonate reservoir, and a 115-ft inactive layer representing the average non-

reservoir interval between the top of the Desert Creek carbonates and the base of the upper Ismay over Runway field.

A total of nine lithotypes were recognized from the Runway cores, which formed the basis for generating an architectural model of the Desert Creek reservoir, using a boolean marked-point process for lithotype emplacement between the wells. These reservoir partitions were then populated with porosities, using layer-averaged statistical distributions obtained from the well log and core data. The spatial distribution of porosity was fitted to the average porosity grid (Fig. 5) using a constrained stochastic block-exchange procedure (simulated annealing). A total of 50 equally probable realizations of this hybrid model have been generated, and horizontal and vertical permeabilities estimated using porosity/permeability correlations from core data. These 50 cases are currently being ranked according to a statistical measure of reservoir connectivity. A subset of three or four realizations representing the predominant types of connectivity will be selected, the Desert Creek interval vertically upscaled to 10 layers, and short simulation sensitivity runs will be carried out to evaluate the impact of heterogeneity on reservoir behavior. The most representative of these cases will then be selected for conducting the flow-simulation history match and reservoir performance predictions.

### ***Technology Transfer***

Project material was displayed at the Utah Geological Survey booth during the American Association of Petroleum Geologists (AAPG) Rocky Mountain Section meeting held in Denver, Colo., August 24-27, 1997. A paper was presented describing the calcarenite reservoir in Heron North field and the potential trend for similar buildups within the Navajo Nation, San Juan County, Utah.<sup>7</sup> An abstract presenting the reservoir characterization and results of modeling of the Runway field was submitted for presentation at the 1998 AAPG Annual Convention in Salt Lake City, Utah.

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