SANDIA REPORT

SAND2006-7159
Unlimited Release
Printed November 2006

Geologic Technical Assessment of the Stratton Ridge Salt Dome, Texas, for Potential Expansion of the U.S. Strategic Petroleum Reserve

Anna Snider Lord, Christopher A. Rautman and Karl M. Looff

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation,
a Lockheed Martin Company, for the United States Department of
Energy under Contract DE-AC04-94AL85000.
Approved for public release; distribution is unlimited.

Sandia National Laboratories

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

NOTICE: 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, nor any of their contractors, subcontractors, or their employees, make any warranty, express or implied, or assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represent 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, any agency thereof, or any of their contractors or subcontractors. The views and opinions expressed herein do not necessarily state or reflect those of the United States Government, any agency thereof, or any of their contractors.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Telephone:(865)576-8401
Facsimile:(865)576-5728
E-Mail:reports@adonis.osti.gov
Online ordering: http://www.doe.gov/bridge

Available to the public from
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Rd
Springfield, VA 22161

Telephone:(800)553-6847
Facsimile:(703)605-6900
E-Mail:orders@ntis.fedworld.gov
Online order: http://www.ntis.gov/help/ordermethods.asp?loc=7-4-0#online

SAND 2006-7159

Unlimited Release
Printed November 2006

Geologic Technical Assessment of the Stratton Ridge Salt Dome, Texas, for Potential Expansion of the U.S. Strategic Petroleum Reserve

Anna Snider Lord and Christopher A. Rautman
Geotechnology and Engineering Department
Sandia National Laboratories
Albuquerque, New Mexico 87185-0706

Karl M. Looff
Geologic Consultant
P.O. Box 546
Lovelady, Texas 75851

Executive Summary

The Stratton Ridge salt dome is a large salt diapir located only some ten miles from the currently active Strategic Petroleum Reserve Site at Bryan Mound, Texas. The dome is approximately 15 miles south-southwest of Houston. The Stratton Ridge salt dome has been intensively developed, in the desirable central portions, with caverns for both brine production and product storage.

This geologic technical assessment indicates that *the Stratton Ridge salt dome may be considered a viable, if less-than-desirable, candidate site for potential expansion of the Strategic Petroleum Reserve* (SPR). Past development of underground caverns significantly limits the potential options for use by the SPR. The *current conceptual design layout* of proposed caverns for such an expansion facility is based upon a decades-old model of salt geometry, and it *is unacceptable*, according to this reinterpretation of salt dome geology. The easternmost set of conceptual caverns are located within a 300-ft buffer zone of a very major boundary shear zone, fault, or other structural feature of indeterminate origin.

This structure transects the salt stock and subdivides it into an shallow western part and a deeper eastern part. In places, the distance from this structural boundary to the design-basis caverns is as little as 150 ft. A 300-ft distance from this boundary is likely to be the minimum acceptable stand-off, from both a geologic and a regulatory perspective. Repositioning of the proposed cavern field is possible, as sufficient currently undeveloped salt acreage appears to be available. However, such reconfiguration would be subject to limitations related to land-parcel boundaries and other existing infrastructure and topographic constraints.

More broadly speaking, the past history of cavern operations at the Stratton Ridge salt dome indicates that operation of potential SPR expansion caverns at this site may be difficult, and correspondingly expensive. Although detailed information is difficult to come by, widely accepted industry rumors are that numerous existing caverns have experienced major operational problems, including salt falls, sheared casings, and unintended releases of stored product(s). Many of these difficulties may be related to on-going differential movement of individual salt spines or to lateral movement at the caprock-salt interface. The history of operational problems, only some of which appear to be a matter of public record, combined with the potential for encountering escaped product from other operations, renders the Stratton Ridge salt dome a less-than-desirable site for SPR purposes.

Contents

Figures

Tables

Plates

Introduction

Stratton Ridge salt dome is one of several domes identified as possible candidates for potential expansion of the nation's Strategic Petroleum Reserve (SPR). The SPR currently consists of underground storage sites, with a total capacity of 727 million barrels of crude oil, at four locations along the Gulf Coast of Texas and Louisiana. The locations of the four storage operating SPR sites are indicated in figure 1. The Energy Policy Act of 2005, which was signed into law on August 8, 2005, calls for expansion of the SPR storage capacity to its full, authorized 1 billion barrels. Although some of this expansion will be accommodated by the construction of additional storage capacity at one or more of the existing SPR sites, the magnitude of the required expansion dictates that at least one new site be considered. The act states that a new SPR expansion site(s) must be selected one year after enactment.

This report describes the geology of the Stratton Ridge salt dome, as it relates to selection of this site for potential SPR expansion. The description utilizes the best information readily available from the literature and petroleum industry sources. However, the short time frame provided by the Energy Policy Act of 2005 has limited, to some extent, the amount of information and objective data that could be acquired, evaluated, and incorporated into the geologic model of the site.

The interpretations of this technical assessment are broadly compatible with previous characterization studies. Some additional information has been obtained, and geologic concepts developed since the last geologic characterization of this site have been incorporated.

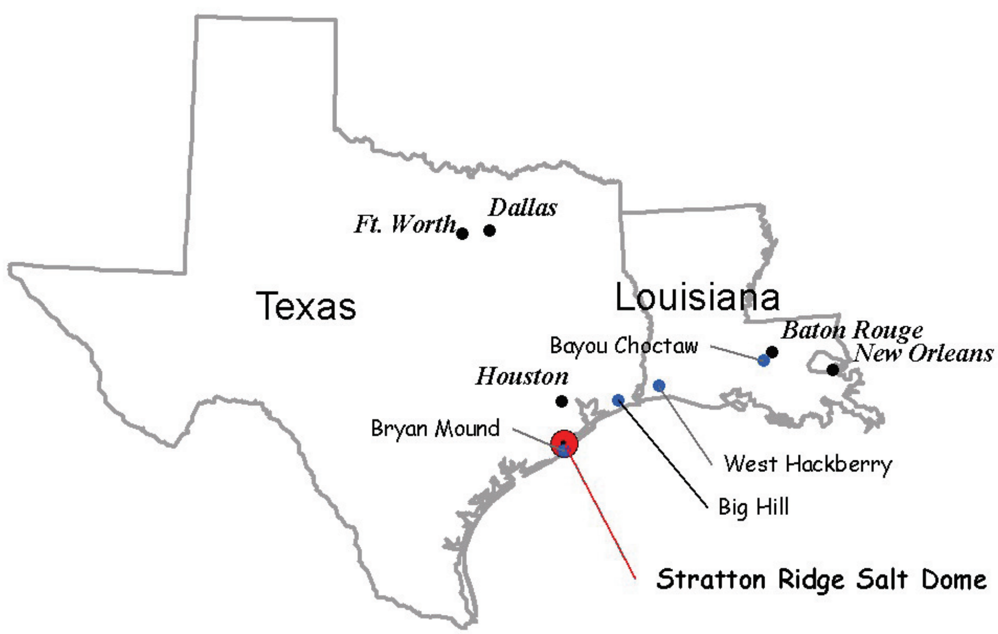


Figure 1. Index map showing the location of the four existing facilities of the U.S. Strategic Petroleum Reserve along the Gulf Coast of Texas and Louisiana, plus the location of the Stratton Ridge salt dome in southeast Texas.

Geology of the Stratton Ridge Salt Dome

Background

The Stratton Ridge salt dome is located in Brazoria County, Texas, approximately 15 miles to the south-southwest of Houston (fig. 1). The dome is located approximately 5 miles due north of the town of Freeport, and roughly 10 miles to the north of the active Strategic Petroleum Reserve facilities at Bryan Mound. The salt dome is of the large, shallow-piercement type. The dome has been used extensively by industry for brining operations and for the storage of liquid hydrocarbons, refined products, and natural gas.

The Stratton Ridge salt dome was discovered in 1913. It is roughly oval in outline, approximately two miles by one-and-a-half miles in lateral extent, with its long axis oriented southwest to northeast. The shape of the dome has been defined by several hundred oil and gas wells, which have been drilled on the flanks since approximately 1922, when commercial hydrocarbon production was first established. The flank wells are concentrated along the southern and northeastern flanks of the dome, where the majority of commercial hydrocarbon production was obtained between the 1950s and the 1970s. Numerous shallow and cavern-related wells have drilled over the top of the diapir. No sulphur mining has been conducted at this dome.

The geometry of the Stratton Ridge salt dome is quite remarkable, and it is considered to be highly anomalous, in comparison with typical Gulf Coast salt diapirs. The top of the eastern one-third of the Stratton Ridge dome is depressed at least 1000 ft with respect to the western two thirds. Furthermore, within that structurally low eastern one-third area is a north-south elongate "basin". An additional 1000 ft of (deeper) structural relief defines this basinal feature. Additional details of this unusual geometry are presented in later sections of this report.

Cavern operations at Stratton Ridge historically are known to have experienced a number of problems. These difficulties and "off-normal events" include severe lost-circulation problems while drilling through caprock, sheared well casings, and wells that encountered hydrocarbon products which appear to have escaped from storage caverns.

Many of these operational issues appear to be caprock related. Sheared casings, in particular, would appear to indicate active faulting within the caprock, or lateral salt flowage immediately below this horizon. However, detailed information regarding such problems is almost wholly absent in the open geologic and engineering literature. Internal company and consultant reports are virtually never released by the cavern operators, and much of what is widely accepted regarding the operational difficulties at this salt dome would be classified formally as rumor or hear-say. Some discussion of more major operational "anomalies", which are required to be reported to the State, may be found in records of the Texas Railroad Commission, which regulates storage operations in Texas, as well as oil and gas operations generally. Although it might be possible to identify a great deal regarding the reported operational problems at Stratton Ridge in this manner, we have not pursued this avenue of investigation at this time.

The unusual geometry of the salt diapir — including the large structural depression in the eastern third of the dome — indicates that the internal salt structure is very complex. Complexity is also implied by the features and problems associated with the caprock, which are most likely caused by active salt movement,. The internal structure and fabric of the salt is likely to influence construction and operation of any SPR caverns constructed at this site.

Data

Data for this characterization study and technical assessment of the Stratton Ridge salt dome were acquired from numerous sources. A database containing the identification and locations of oil industry wells was acquired from Tobin International, known also known as P2 Energy Solutions (http://www.tobin.com)[1], a commercial vendor of well and land-survey data. Additional wells were identified using the internet web site of the Texas Railroad Commission (http://webapps.rrc.state.tx.us/). Geophysical well logs, oil-industry scout tickets and well completion cards were also obtained from commercial oil-industry sources, as well as from in-house files. Existing published tabulations of salt contacts and formation tops were also integrated into the data set.

There are a total of 345 documented wells that have been drilled in the immediate vicinity of the Stratton Ridge salt dome. The majority of these wells are shown in figure 2, and a larger-scale map of the well locations is included as Plate 1. Of the total number of wells, Sandia was able to acquire 147 electric/induction well logs and/or scout and completion cards from oil-industry sources. A complete listing of these 147 control points is presented in Appendix A. Why we were unable to obtain meaningful geologic information from the remaining known wells is unclear. However, we do know that commercial well-log vendors do not always track cavern-related wells as closely as they do more conventional hydrocarbon exploration holes.

A three-dimensional seismic survey was acquired over the Stratton Ridge dome a number of years ago (~1990s). Inquiries have determined that these data are not currently on the market, and the information and specific details remain proprietary. However, personal communication with individuals knowledgeable about the survey results indicates that the general shape of the dome, outlined herein, is confirmed. Furthermore, these discussions have indicated that additional salt overhangs, other than those readily identifiable from well control, are present in several locations.

Caprock

Caprock is present at Stratton Ridge at a minimum subsea depth of about 850 feet. The caprock at Stratton Ridge is several hundred feet thick; limestone, gypsum, and anhydrite facies are all reported. A structure contour map showing the geometry of the top of caprock is presented on Plate 2. A reduced-scale version of this map is shown as figure 3. The mapped geometry of the caprock indicates that the Stratton Ridge dome is generally circular in plan view, with a somewhat blocky extension toward the west-southwest. The flanks of the caprock, and of the deeper salt, are quite irregular in plan view. There are also several separate, well-defined structural culminations over the western portion of the dome crest.

The caprock map of figure 3 indicates that the Stratton Ridge dome can be subdivided into two major regions. In the western portion, constituting roughly two-thirds of the dome area, caprock is present ubiquitously above an elevation of 1500 ft, subsea, and the overall crest is fairly flat at elevations of approximately 1100 to 1000 ft, subsea. A large number of individual, quasi-circular to elliptical regions appear elevated above the –1000-ft level. The shallowest documented caprock is at –840 ft, and this intercept is located along the extreme southwestern margin of the dome (Dow Chemical Brock No. 5B; well 31767 in Appendix A, page 36). At least one northeast-trending fault can be mapped, constrained by identifiable offsets in pairs of closely spaced wells.

[1] The use of firm, trade, or brand names in this report is for identification purposes only and does not constitute endorsement by Sandia National Laboratories.

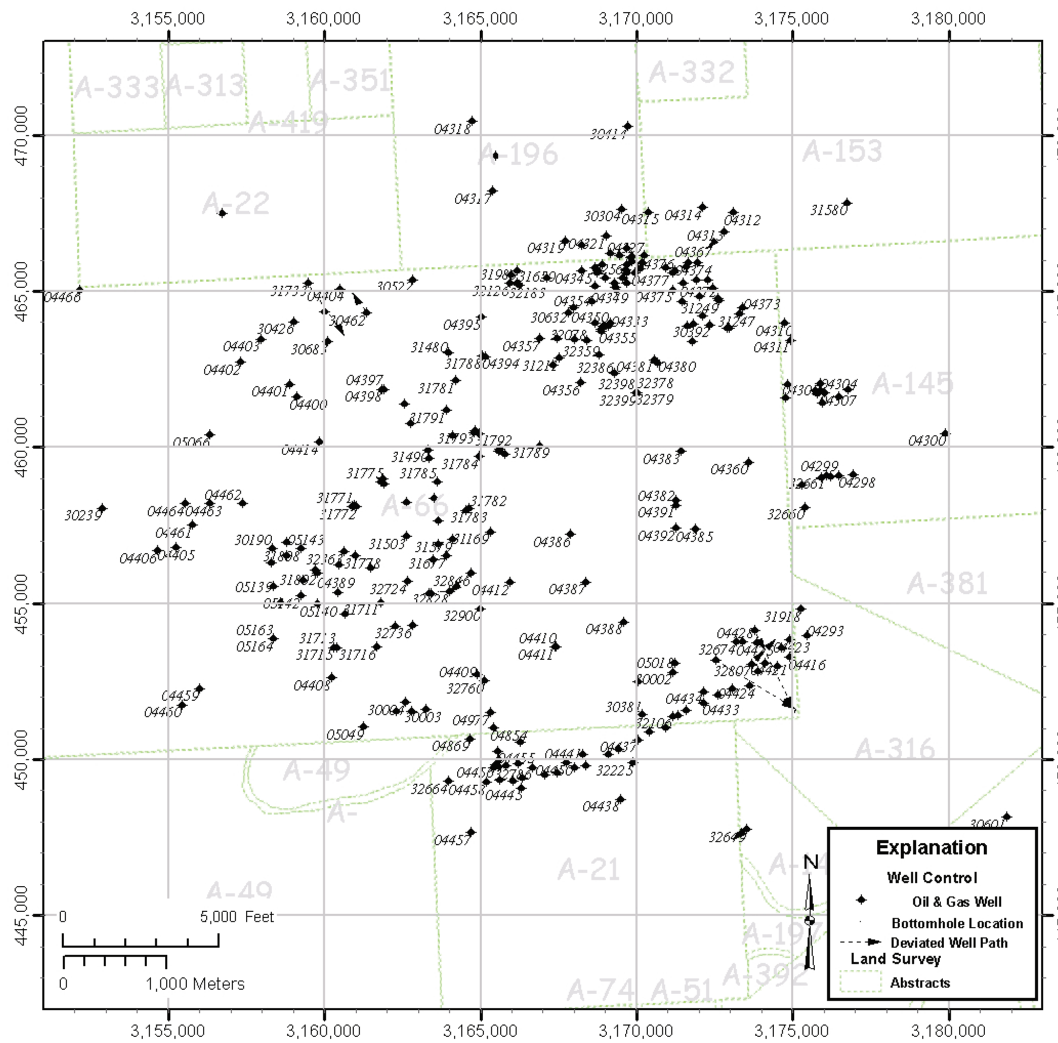


Figure 2. Map showing locations of oil, gas, and other wells identified in the vicinity of the Stratton Ridge salt dome. Five-digit numbers are "short API" numbers. Coordinates are Texas state plane values, south-central zone, NAD27, in feet. Refer to Plate 1.

The eastern one-third of the dome is dominated by a large depression. This depression, which is broadly basinal in form, is separated from the elevated western portion of the salt stock by a relatively sharp, more-or-less north–south structural break of roughly 1000 vertical feet. The basin is generally elongate from north to south, and the dimensions are at least 8000 by 6000 ft (fig. 3).

The deepest caprock intercepts within the depression are an *additional* 1000-plus feet below the base of the pronounced structural break, which bounds the basin to the west. The eastern margin, or "rim", of the basin is at approximately this same subsea elevation. The top surface of the Stratton Ridge salt dome is generally deeper than 2000 ft, subsea throughout this eastern region. However, a very small domal high, which extends above 1400 ft, subsea, to elevations similar to those of the western portion of the dome, is present immediately to the north of the structural depression.

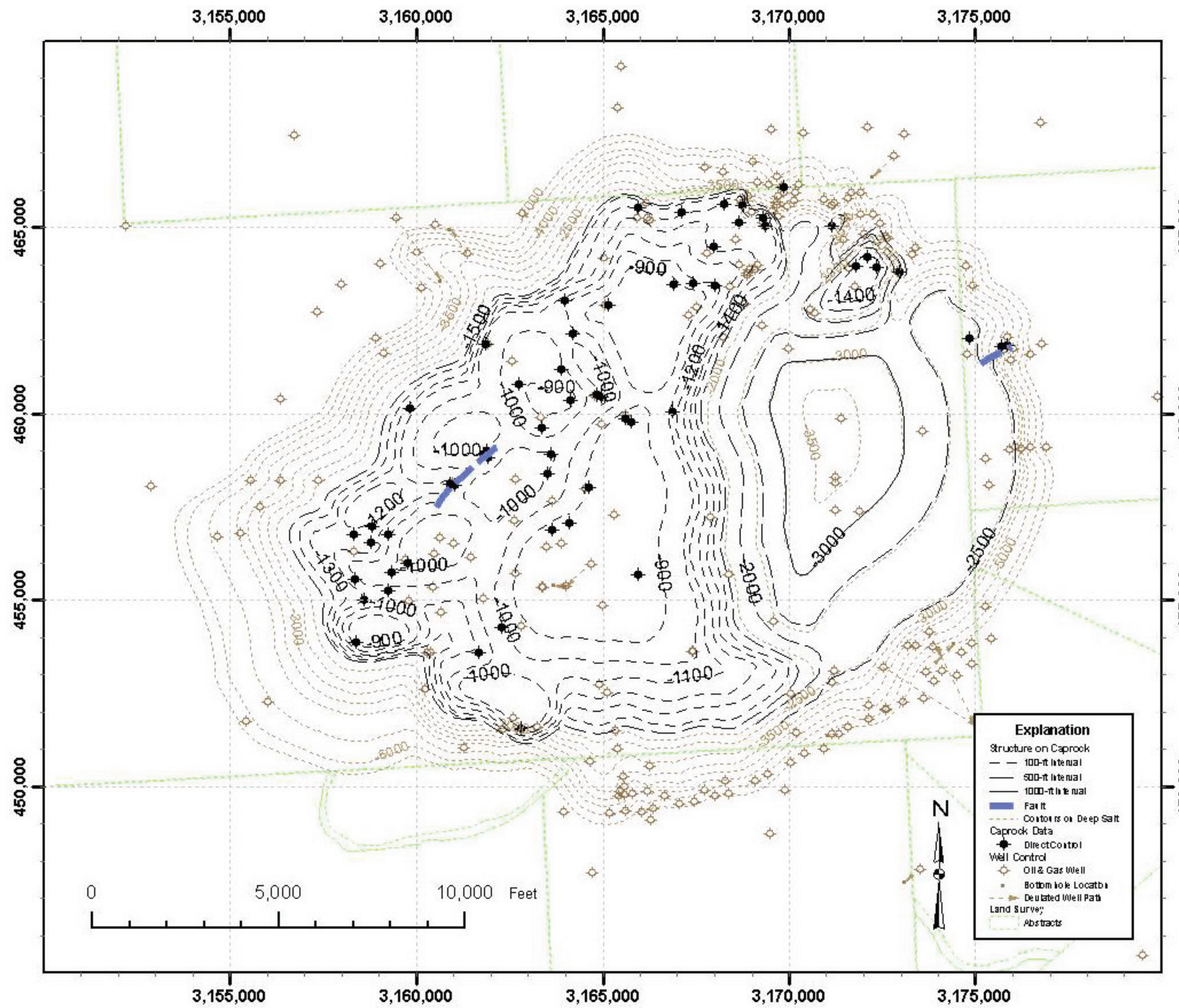


Figure 3. Structure contour map of the Stratton Ridge salt dome, drawn on the top of caprock. See Plate 2 for full-scale map. Coordinates are Texas state plane values, in feet. Elevation datum is mean sea level.

Full resolution of the detailed geometry of the caprock is beyond the limits of the available well information. This is particularly true for the northeastern portion of the dome and in the vicinity of the small domal structure just described. It is clear, however, that the structure is complex. We attempt to compensate for the incompleteness of the detailed caprock structure map by including on figure 3 the structure contours for the deeper continuation of the overall Stratton Ridge domal form. These contours are shown on Plate 2 and on figure 3 in a different (lighter-weight and dashed) line type, and they are drawn principally on the salt flank, rather than on caprock, per se. The resulting composite map is more representative of the overall geometry than would be possible otherwise.

The structure contours shown in figure 3 have been digitized and converted to a three-dimensional computer model for visualization using the methodology from Rautman and Stein (2003). A map view of the resulting model of the Stratton Ridge caprock, showing the structure on the top of caprock is presented as figure 4. The surface is color-coded by its subsea elevation; the deeper flanks of the salt stock itself are represented by the grey surface. The subdivision of the salt stock into two significantly different portions is immediately obvious, based upon the difference in elevation colors. The abrupt, and somewhat curvilinear, nature of the structural break between the two sections of the dome is also rendered quite clearly in this visualization.

Two perspective views of this same three-dimensional caprock model are presented in figure 5. Figure 5(a) is a view from the southwest, and part (b) of the same figure is a view from the southeast. The visualizations enhance the presence of the depression to the east, the form of the marked structural break, and the several discrete structural culminations along the western crest.

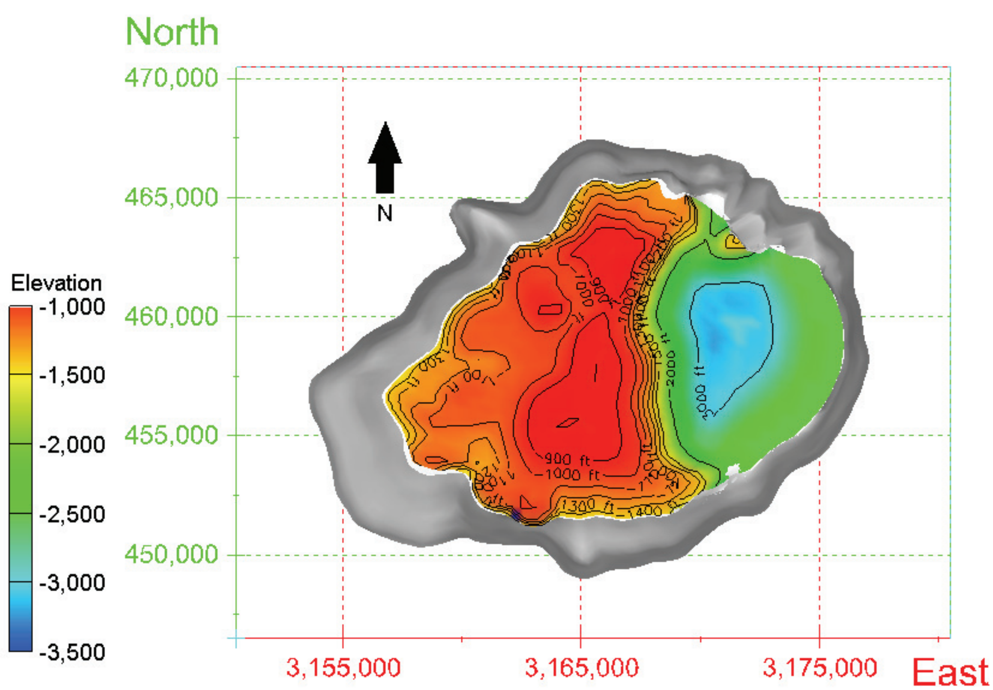


Figure 4. Map view of the three-dimensional model of the Stratton Ridge salt dome, showing the geometry of the top of the caprock. Note the pronounced subdivision of the overall dome into a western and an eastern portion.

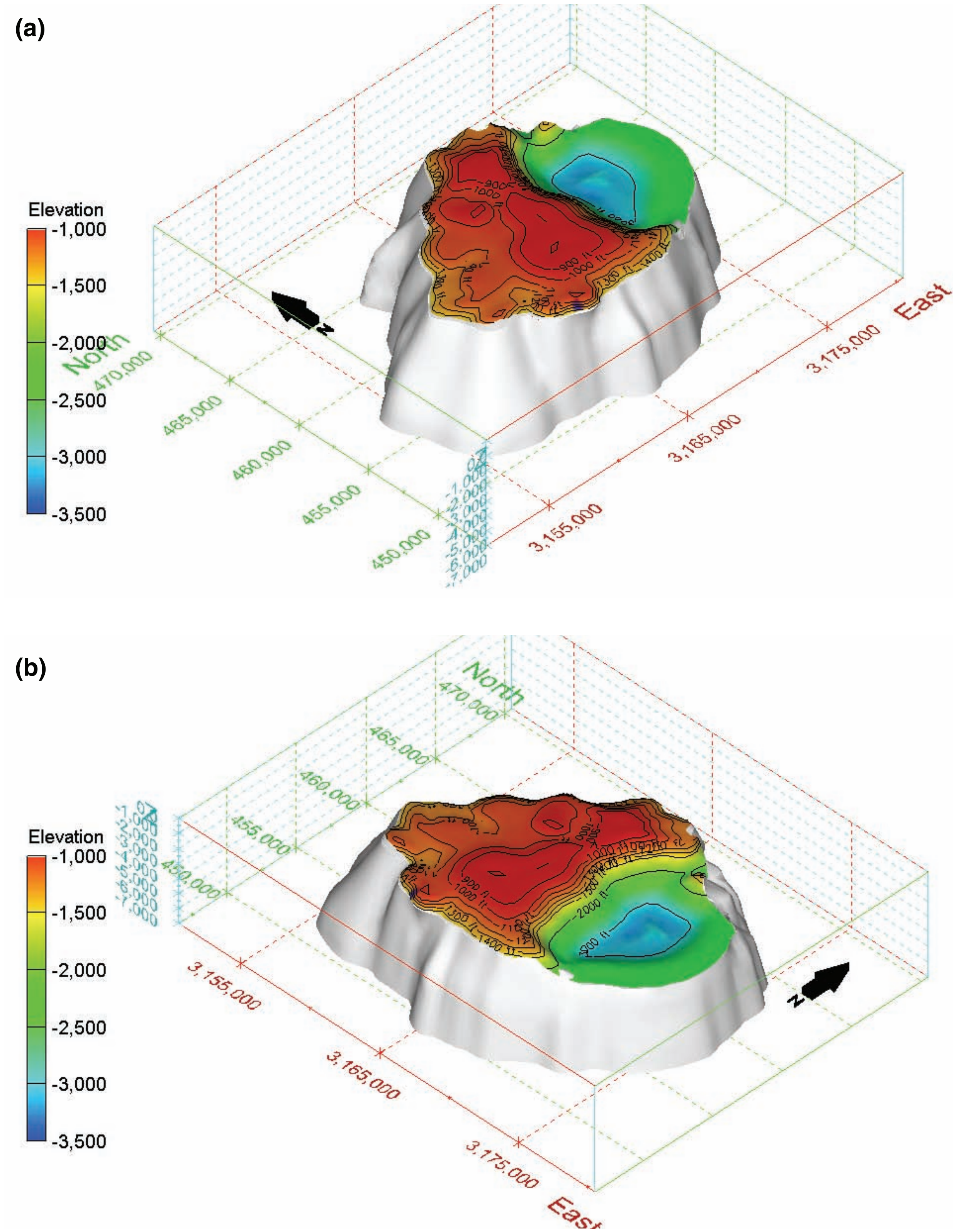


Figure 5. Perspective views of the 3-D model of the Stratton Ridge salt dome, showing the structure of the caprock, including the major structural depression of the eastern third of the dome. Views (a) from the southwest; (b) from the southeast.

The geometry of the caprock at Stratton ridge, in general, is relatively well constrained by drill hole data. Figure 6 portrays the spatial distribution of wells and control points over the Stratton Ridge dome, both for caprock and for salt. Direct well control (blue markers) consists of actual well intercepts of the top-of-caprock (or top-of-salt) surface. The direct control points are located predominantly over the western and northern regions of the dome. Indirect control (red markers in fig. 6) was also used to help define the dome flanks, particularly along with the eastern and southern areas of the dome.

Indirect control is generally, but not exclusively, derived from wells which either were not drilled deep enough to encounter a particular horizon, or for which the necessary direct evidence (e.g., a geophysical well log showing the contact) is not available. Total depths of wells, such as might be obtained from an oil industry scout ticket or well completion card, indirectly constrain the (minimum) depth to a particular contact, such as of the top of caprock or salt. Total depths for both direct and indirect control points are shown in the perspective views of the Stratton Ridge dome in figure 7. Control of the dome geometry at Stratton Ridge is generally quite good.

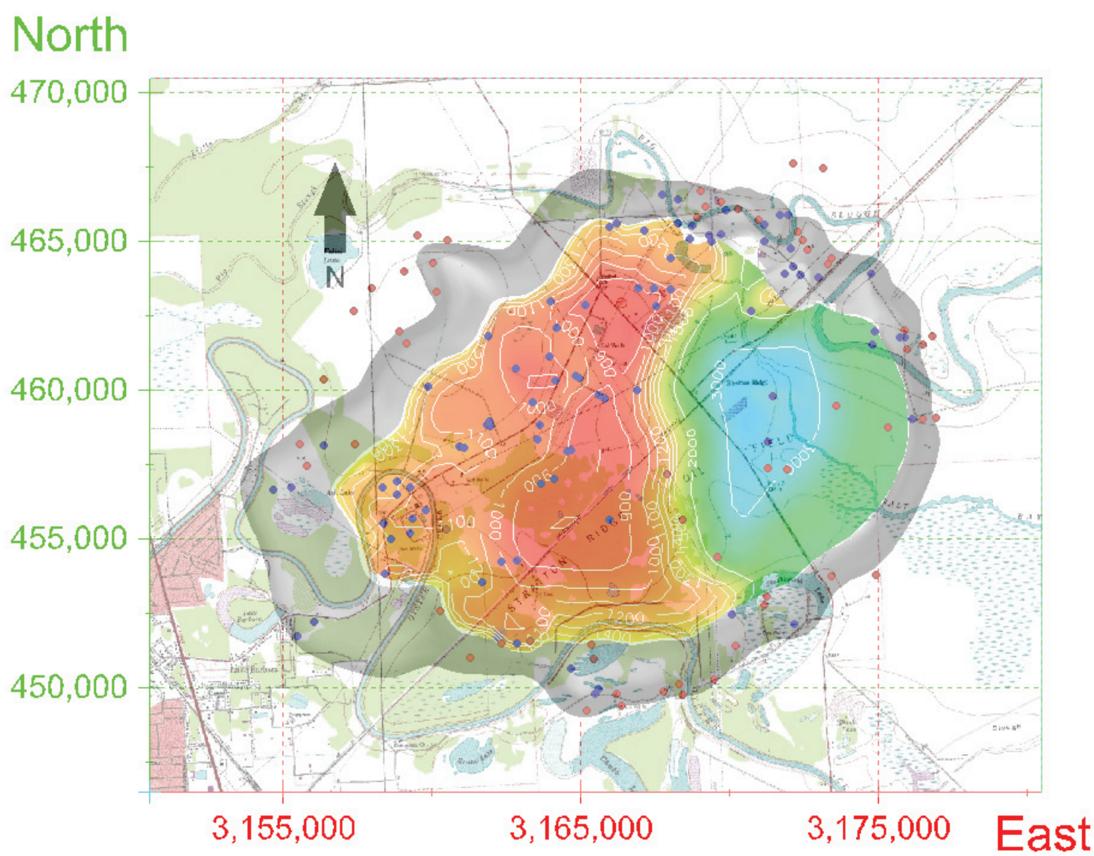


Figure 6. Map view showing overall outline of the Stratton Ridge salt dome and the available well control used to map geometry of the salt stock and caprock. Blue locations represent direct well control, whereas red locations represent indirect control. Colored region and structure contours represent geometry of the caprock surface. Topographic base from U.S. Geological Survey Oyster Creek and Lake Jackson 7-½-minute quadrangle maps (1:24,000).

(a)

(b)

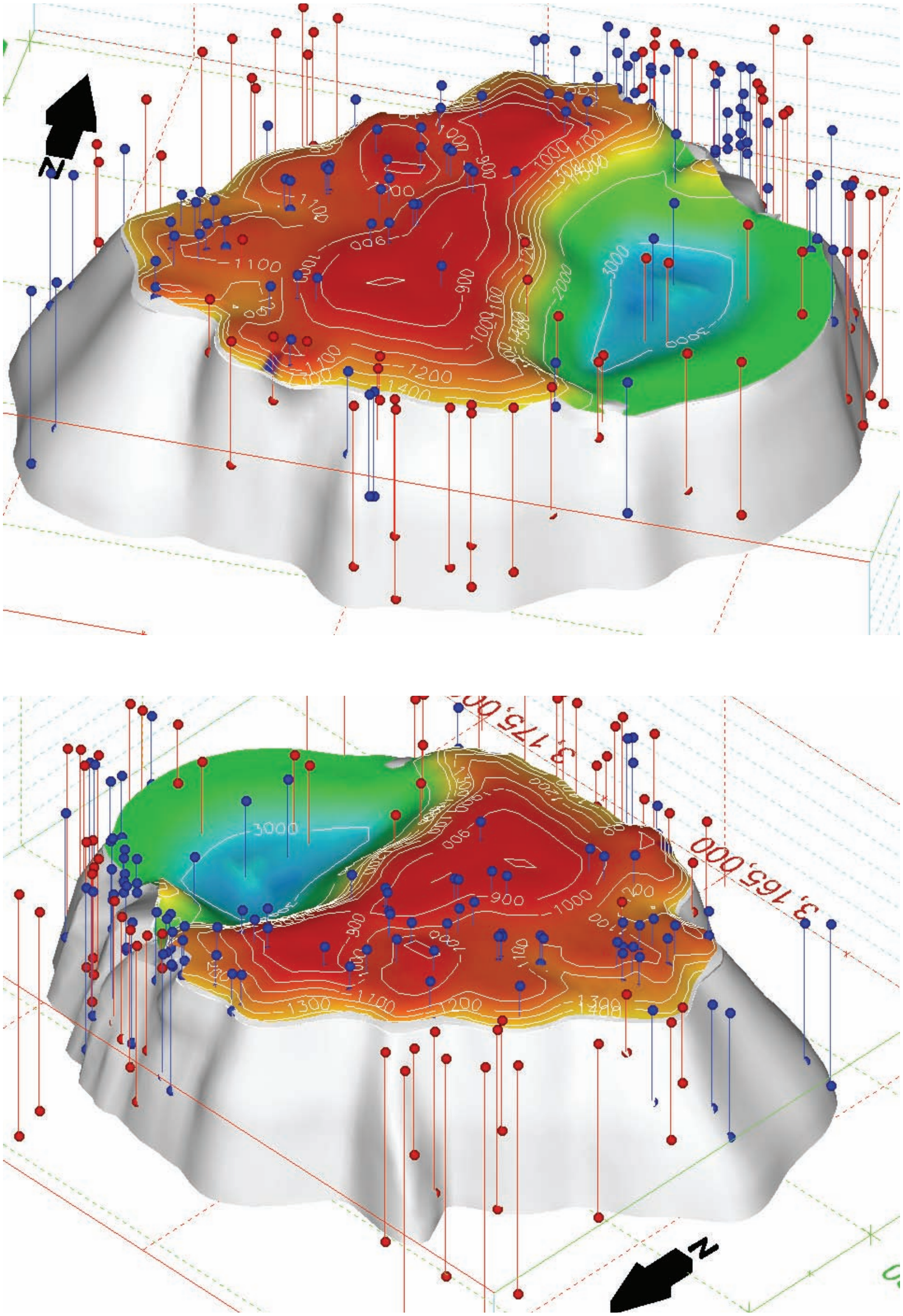


Figure 7. Perspective view well control in the vicinity of the Stratton Ridge salt dome from the (a) southeast and (b) northwest. Blue symbols indicate direct well control points; red symbols indicate indirect control.

Salt

Structure contours drawn on the top-of-salt surface are presented in Plate 3 and in figure 8. As was the case for the geometry of the overlying caprock surface, the two-part subdivision of the dome is quite marked. The western portion of the top of salt is at shallower elevations than the eastern portion, and the broad structural (?) basin in the eastern part is well developed. The vertical extent of the break separating the two structural domains is less extreme than for the caprock: ~600 ft vs. more than 1000 ft. Similarities in the elevation (~2000 ft, subsea) of the extreme eastern margin of the eastern structural depression to that indicated for the caprock, as shown on the maps of figures 3 and Plate 2, suggests that caprock may be almost wholly absent along this eastern portion of the dome.

The crest of the salt mass in the western portion of the dome is noticeably flatter than the corresponding crest of the caprock. Elevations are typically 1300–1400 ft, subsea. A number of discrete elevated regions are identifiable, although the relief of these features is subdued. Two small areas of overhang are present, one to the south-southwest and the other to the north, immediately to the west of the structural break. The southern overhang is present between –1500 and –4000 ft, whereas the northern overhang is present from a subsea elevation of roughly –2500 ft to approximately –4000 ft.

Below a structural elevation of about –1500 ft, the dome flanks plunge steeply downward to at least 7000 ft below sea level. On the southwest, the flank dips somewhat more gently below 4000-ft depths. The flanks exhibit a crenulated pattern around the entirety of the Stratton Ridge salt dome.

The eastern part of the dome is dominated by the large structural depression. The depression is elongate from north to south and reaches a elevation below –3500 ft. A small fault may be mapped east of the depression, along the flank of the dome. A small structural high, mirroring that identified in the same spatial position within the caprock, is present north of the main structural low. The shallowest salt point also located in this region, at an elevation of –1272 ft. This structural high represents a complex region beyond the resolution of the existing and available subsurface control.

Figure 9 represents a top view of a three-dimensional computer model of the structure contour map of figure 8, converted using the same digitization and modeling techniques used for the caprock and based on the work of Rautman and Stein (2003). The salt surface is color-coded by the subsea elevation. Two perspective views of this same three-dimensional model are presented in figure 10. Figure 10(a) presents a view from the southwest, and part (b) of the same figure is a view from the southeast. Both figures 9 and 10 clearly represent the major two-fold subdivision of the Stratton Ridge salt dome. The low relief nature of the western part of the dome crest is also evident.

Discussion

Boundary Shear Zones

Geometric segmentation of a salt dome is generally taken to indicate that the salt stock consists of more than one salt spine or spine complex. Spines and spine complexes are generally accepted as separated by boundary shear zones, along which the differential movement of salt has been accommodated. This situation definitely applies to the Stratton Ridge salt mass, as the overall two-fold geometric subdivision of this dome is clearly incompatible with an interpretation of emplacement as a single salt plug. As noted previously, the geometry of the upper part of the Stratton Ridge salt dome, for both the caprock and top-of-salt sur-

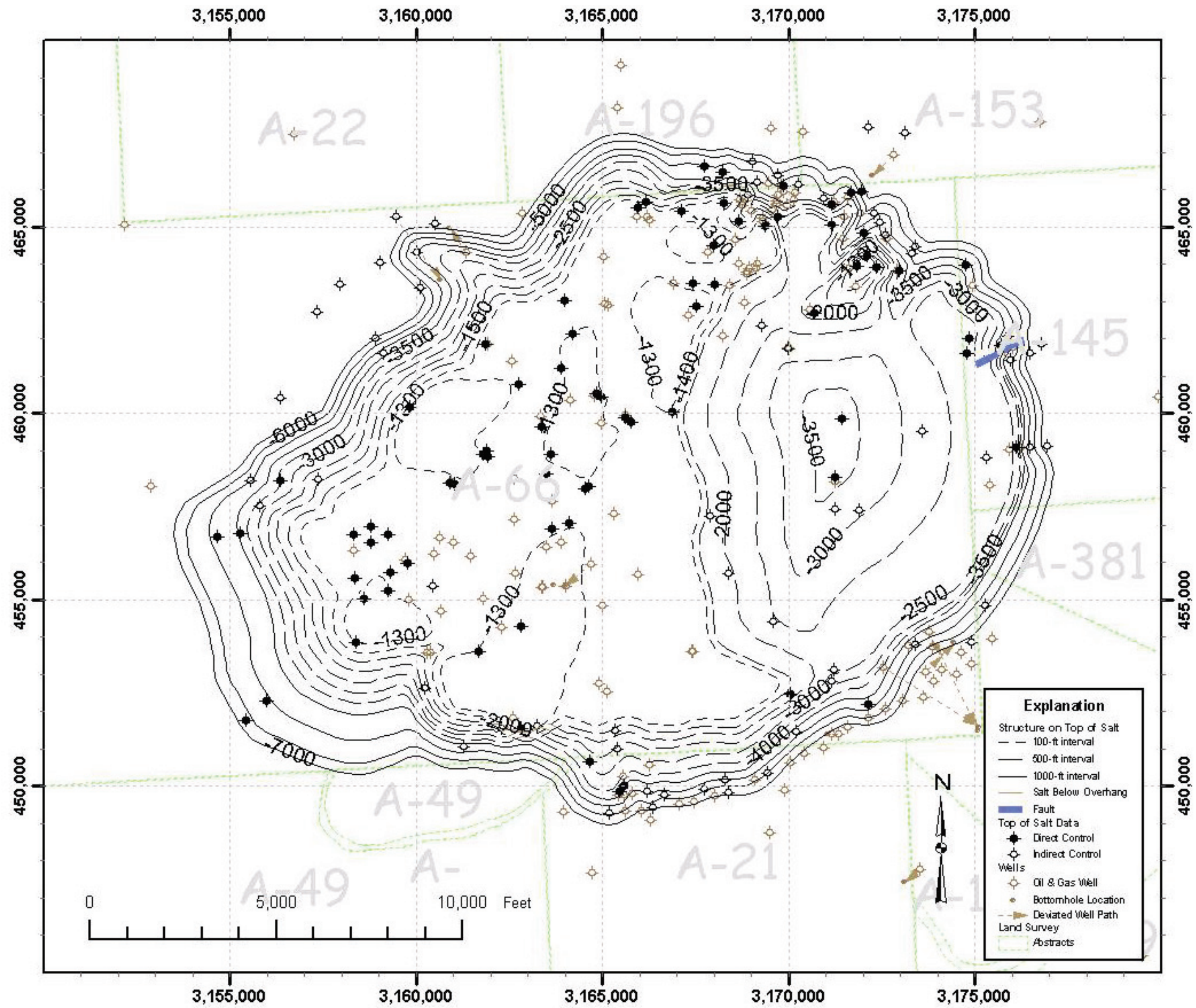


Figure 8. Structure contour map of the Stratton Ridge salt dome drawn of the top of salt. See Plate 3 for full-scale map. Coordinates are Texas state plane values, in feet. Elevation datum is mean sea level.

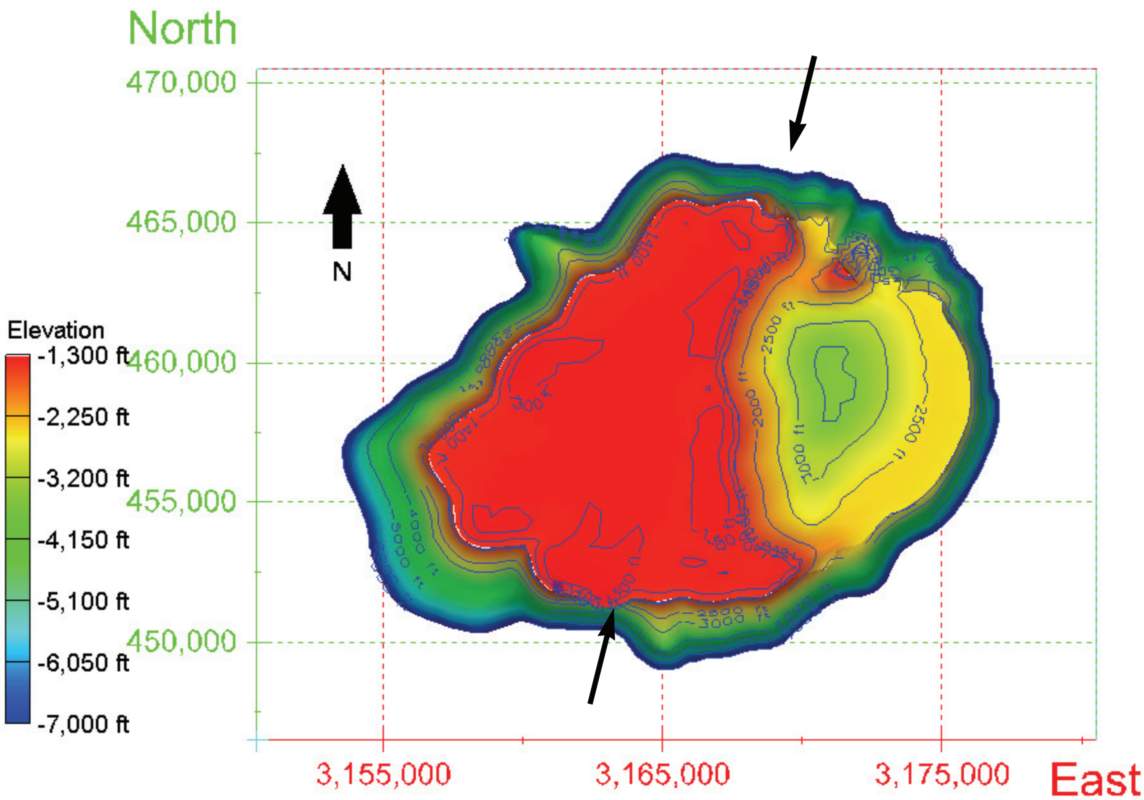


Figure 9. Map view of a 3-D model of the Stratton Ridge salt dome, showing the structure on the top of salt. Structural relief on the crest of the western portion of the dome is generally less pronounced than for the caprock. The structural depression of the eastern portion of the dome is expressed clearly. Arrows highlight regions exhibiting structural overhang.

faces, is highly anomalous among Gulf Coast salt domes.

Additionally, the presence of several discrete structural highs, separated by intervening swale areas, within the “flatter”, western portion of the Stratton Ridge salt stock is inferred to indicate further subdivision of the salt diapir into a number of still smaller loci of quasi-independent salt movement. This is particularly true for the numerous, and generally well-constrained, contour closures mapped on the top of the caprock (figs. 3, 4).

Caprock overlying salt domes forms as an accumulation of insoluble constituents, which are present within the bulk salt composition and which remain behind as migrating near-surface ground waters dissolve the slowing upwelling salt. Therefore, varying thicknesses of caprock represent — approximately — the positions of portions of the salt mass that have moved differentially with respect to one another. These varying thicknesses of caprock are typically expressed as structural highs, as the underlying top-of-salt surface is generally quite planar, corresponding to the dissolution front at the base of “fresh” ground water.

In the case of the Stratton Ridge salt dome, the structure contour map of figure 3 suggests as many as eight individual salt spines within the elevated western portion of the salt stock. These apparent spines could be aggregated as spine complexes in various ways, and the larger structural culminations could probably be subdivided, were more well-control points, or sufficient seismic data, available. A map

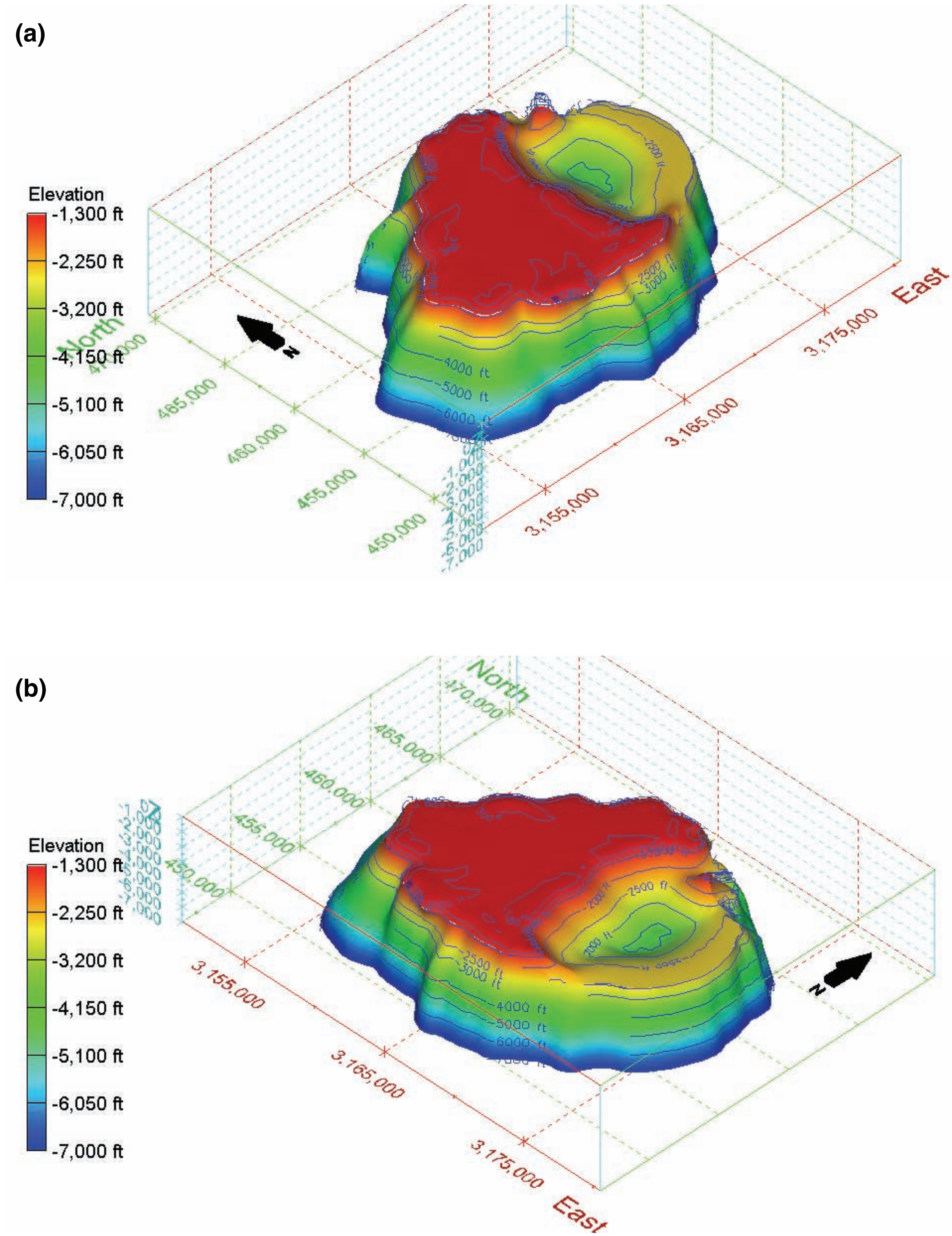


Figure 10. Perspective views of the Stratton Ridge salt dome, emphasizing the structure on the top of salt. View (a) from the southwest; (b) from the southeast.

view of the top-of-caprock surface showing a possible subdivision of the Stratton Ridge salt dome into a number of salt spines, separated by several, more obvious, boundary shear zones, is presented in figure 11.

The major two-fold segmentation of the Stratton Ridge salt dome is not so immediately interpretable in terms of prototypical salt spines or spine complexes. However, such a profound geometric difference must represent a correspondingly profound structural difference within the underlying salt stock. At a minimum, it would appear that the Stratton Ridge salt dome was emplaced in at least two markedly different episodes.

Salt Overhang

Neal and others (1991) present a structure contour map, showing a much simpler top-of-salt geometric configuration of the Stratton Ridge salt dome, in a brief characterization report related to an earlier SPR expansion study. Their illustration is reproduced as figure 12. Although the principal features of the Stratton Ridge dome identified by the current, more detailed mapping effort are present in the older work, there is at least one major difference.

Specifically, the Neal et al. structure map indicates the presence of major salt overhang, extending around approximately one-third of

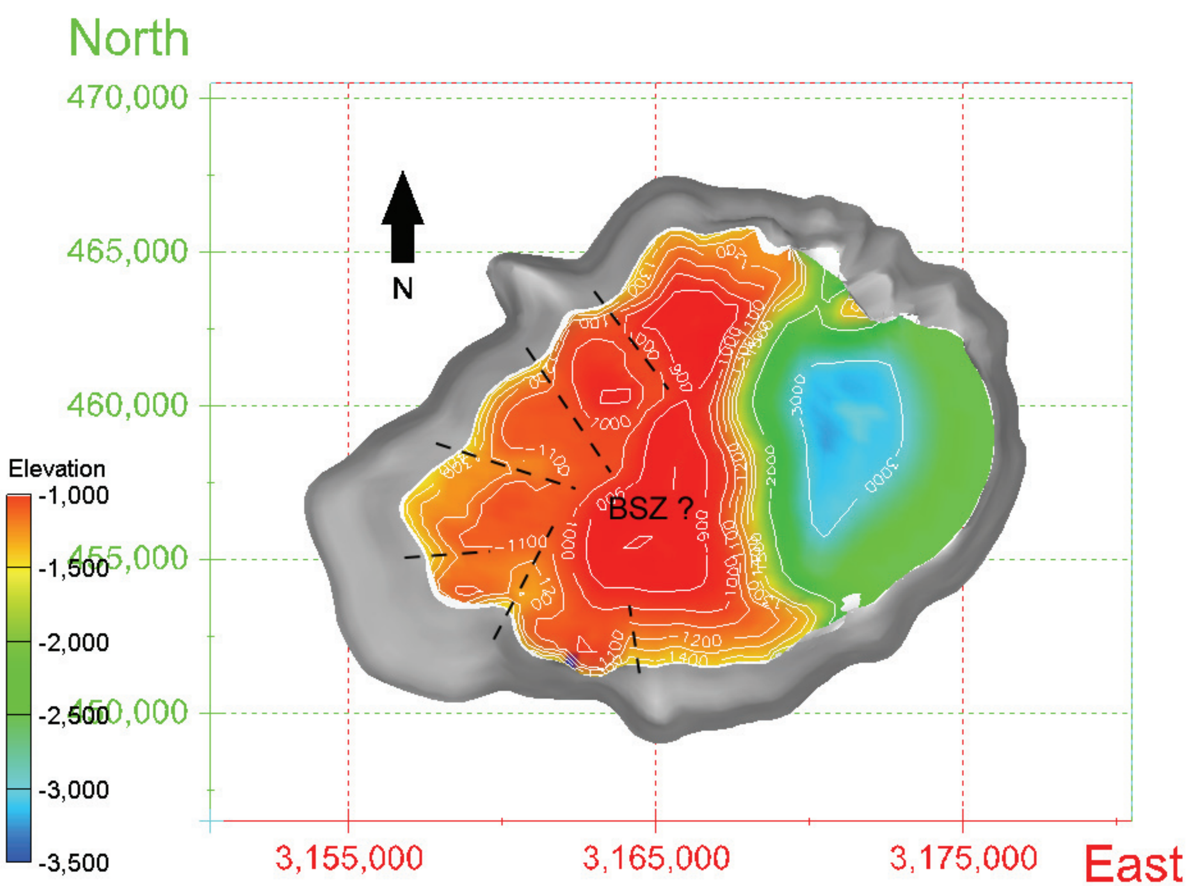


Figure 11. Map view of the three-dimensional model of the Stratton Ridge caprock showing possible subdivision of the underlying salt stock into a number of individual spines and spine complexes. Additional subdivisions of the caprock could be defined.

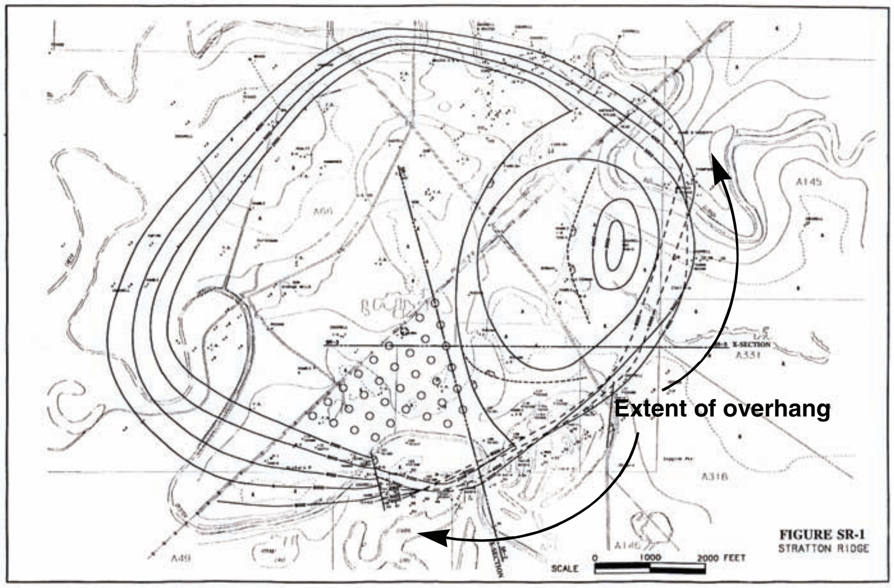


Figure 12. Simplified structure contour map on the top of salt, as mapped by Neal and others (1991).

the dome periphery (fig. 12). The overhang, which is indicated from 2000 ft, subsea, to the base of mapping at 5000–6000 ft depths (the fine print of the contour labels on the published map are obscure), involves the entire eastern and southeastern margin of the dome. The existence of this overhang cannot be wholly excluded by the available open-source data (see earlier remarks regarding the 1990s-vintage 3-D seismic survey on page 9); control in this portion of the dome is largely indirect [fig. 7(a)]. However, we interpret the extent of the overhang as much less, based upon positioning of the salt-sediment contact in a few direct-control well locations.

Neal and others (1991) also cite unpublished (2-D?) seismic work by Cockrell Oil Company, conducted in December 1990, suggesting that the major structural break dividing the Stratton Ridge dome into two segments of differing subsurface elevation, is a “slump fault”, dipping 60° to the east. It is unclear that an actual origin by faulting caused by gravity-driven slumping could be sustained in relatively ductile salt. However, it is clear that some kind of a major structural feature is present in this area, as mapped. Whatever its origin, this feature complicates the use of this salt dome for underground storage. Neal et al. provide less-definitive, oblique references to other seismic surveys by both the Dow Chemical and Amoco Oil (now BP Oil) companies, which purport to show other faulting within the caprock.

Recent Freeport LNG drilling

In August 2005, Freeport LNG Development, LLC, filed permits with the Railroad Commission of Texas (http://webapps.rrc.state.tx.us/) to drill three new wells for liquefied natural gas storage in the southern portion of the Stratton Ridge salt dome. The locations of these three permitted wells are shown in figure 13. The locations are indicated to be positioned within the anomalous southeastern part of the salt stock, and the core test, FLNG Gas Storage No. 1-T, is reported to have been intended to test the southernmost flank of the dome.

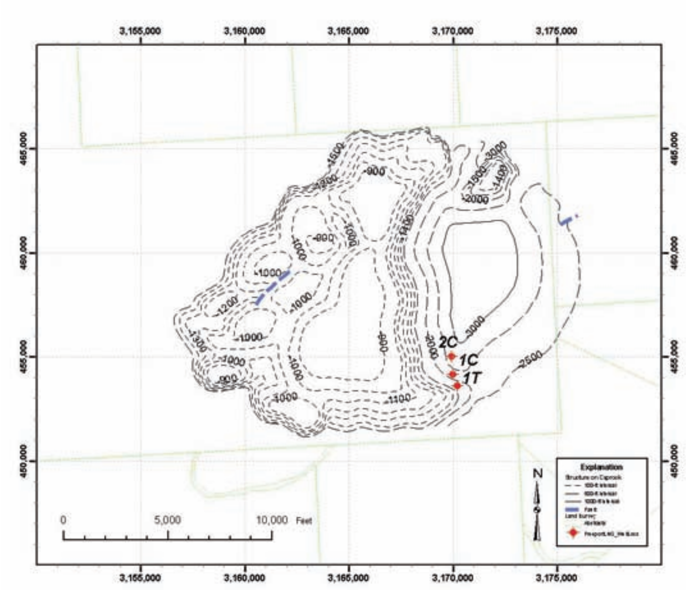


Figure 13. Small-scale index map showing the *permitted* locations of three wells proposed and/or drilled by Freeport LNG Development, L.P., showing relationship to the major segmentation of the Stratton Ridge salt dome. Only the core test, well 1-T, is known to have been drilled. Structure contours are drawn on top of the caprock.

Virtually nothing is known formally regarding the results of this test well, which presumably was cored extensively. However, industry reports are that the entire Freeport LNG venture appears to have been terminated in May 2006. That such a major storage project would have been shelved abruptly, or completely cancelled, suggests that major geologic problems may have been encountered by well 1-T. However, the reported termination of the project is compatible with an interpretation of major structural issues within this southeastern portion of the Stratton Ridge salt dome. There is no evidence available indicating that either of the other two permitted locations were ever drilled.

Conceptual Engineering Design

A preliminary conceptual design for a potential SPR expansion facility at Stratton Ridge has been proposed by PBESS (2006). This conceptual design includes 16 underground storage caverns, of approximately 10 MMB each, arranged approximately as hexagonal close-packing of idealized cylinders, within a crudely triangular parcel of land in the south-central portion of the Stratton Ridge dome. This design layout is reproduced as figure 14, directly from the relevant engineering drawing. Note that the outline of the Stratton Ridge dome, as shown on this engineering drawing, is based upon a decades-old earlier site-characterization report (Neal and others, 1991, fig SR-1).

Figure 15 presents this conceptual design layout, superimposed upon the current best model of the Stratton Ridge salt dome, from figure 8. Note that because the conceptual layout of the proposed caverns is based upon a more generalized interpretation of the top-of-salt structure, the easternmost caverns lie within only 150 ft or so of the mapped major structural boundary between the elevated western part of the salt stock and the depressed eastern portion. Figure 16 is a map view of the three dimensional model of the top of caprock, corresponding approximately to that of figure 15.

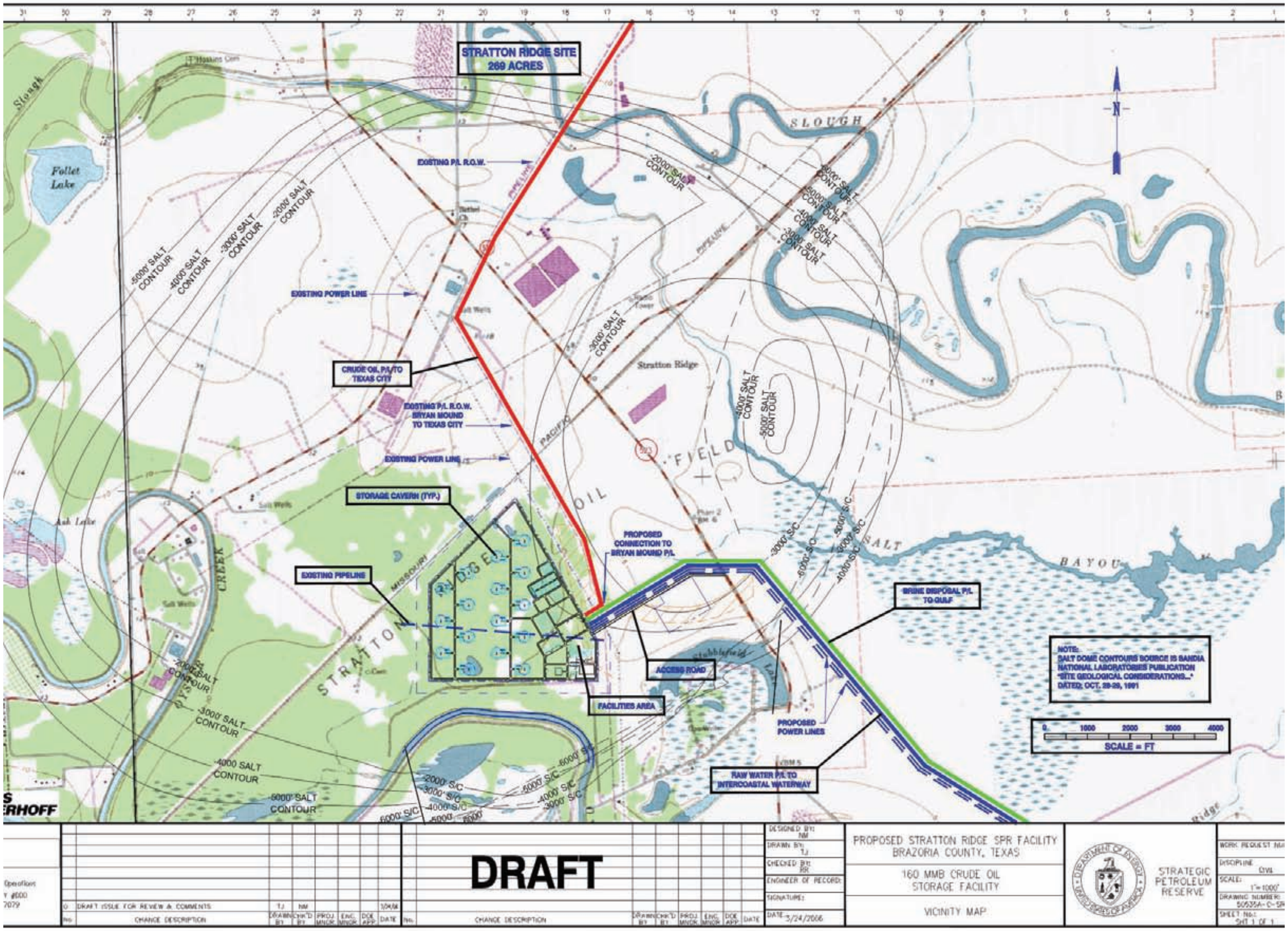


Figure 14. Preliminary conceptual design layout of a potential SPR expansion facility at the Stratton Ridge salt dome. Reproduced from PBESS drawing 50534A-C-SR001 (2006). Structure contours on top of salt represent an outdated model of the Stratton Ridge dome.

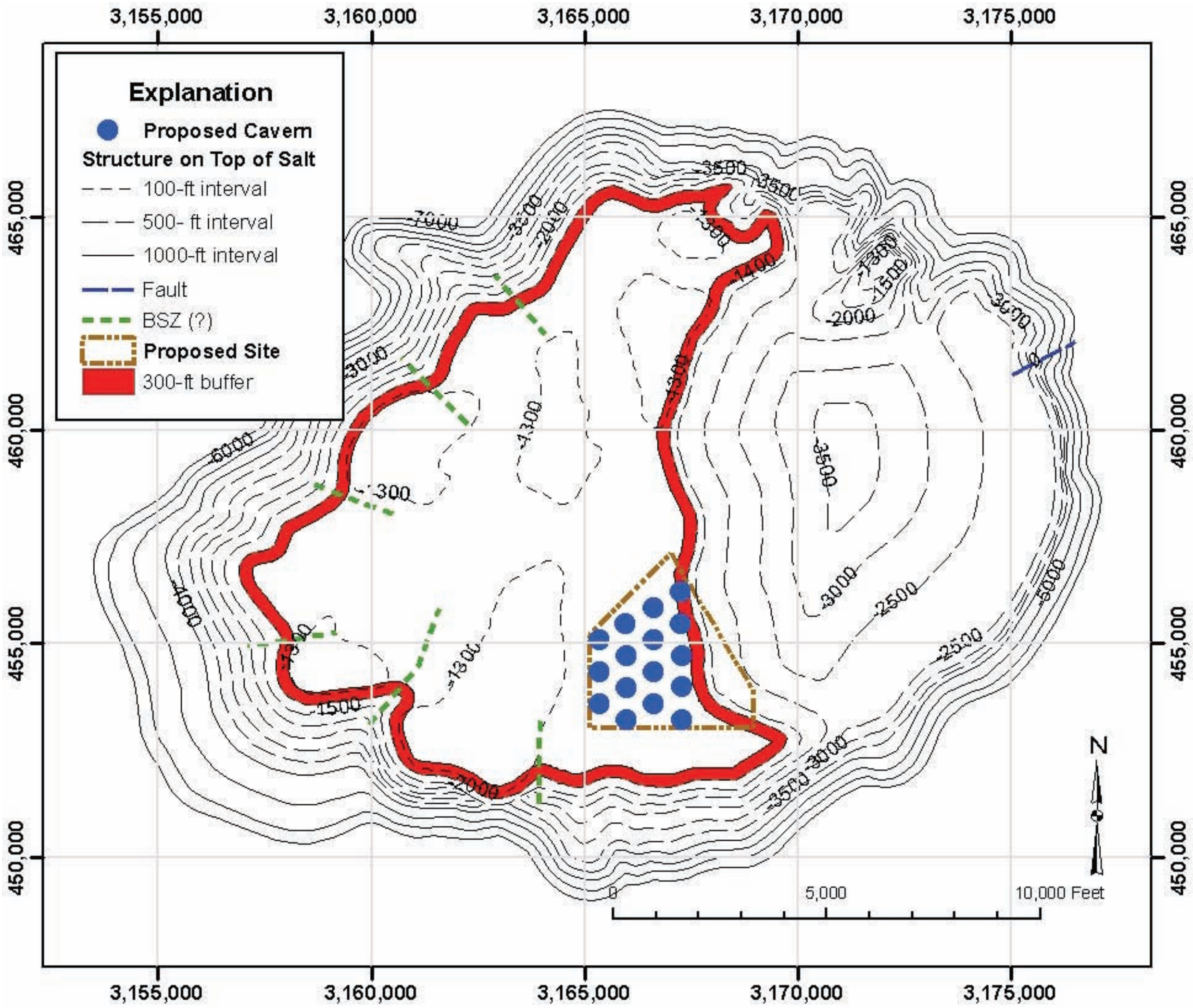


Figure 15. Map view of the Stratton Ridge salt dome showing the conceptual design cavern layout (PBESS, 2006) from fig. 14, above, superimposed on the structure contour map of the top-of-salt surface. Map also shows 300-ft buffer zone extending inward arbitrarily from the top of the major structural break at elevation –1400-ft. Possible boundary shear zones are from map of caprock shown as figure 11. Caverns are only approximately to scale.

Because of the extent of spatial uncertainty associated with this mapped boundary, the conceptual design location clearly is unacceptable. Additionally, because the structural elevation of the depressed, eastern top of salt is approximately 2000 ft below sea level, the diagonal distance to the salt margin from the northeastern-most cavern roof, at an elevation of roughly 2500 ft subsea, would be substantially less than anticipated, were the true top of salt at the –1400 ft elevation otherwise prevailing. Figure 17 presents a typical east-west cross section representing the geometry of the conceptual design caverns to the major structural break transecting the Stratton Ridge salt dome.

As the true nature of the structural break and the origin of the depressed eastern part of the Stratton Ridge salt stock are unknown, locating the proposed SPR expansion caverns in this position poses severe risks to the

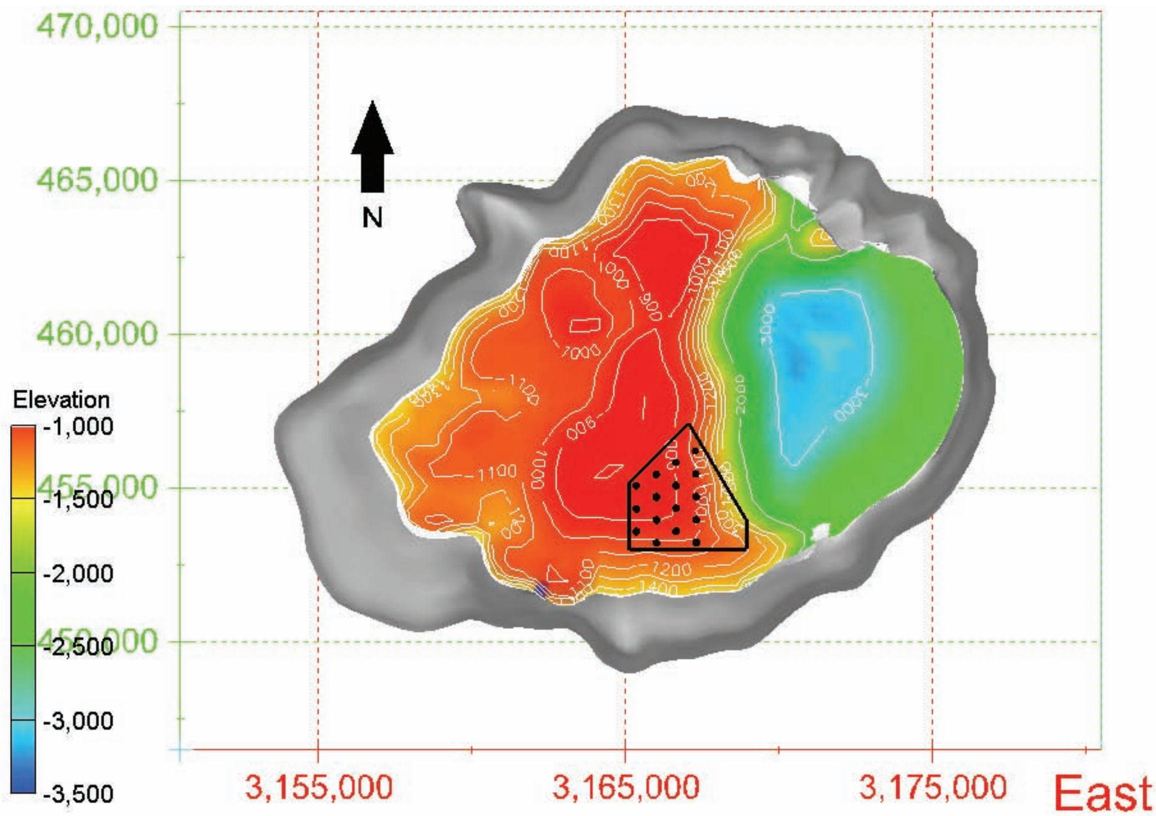


Figure 16. Top view of the Stratton Ridge salt dome showing the conceptual design of the proposed SPR expansion site and potential cavern locations (PBESS,2006) in blue.

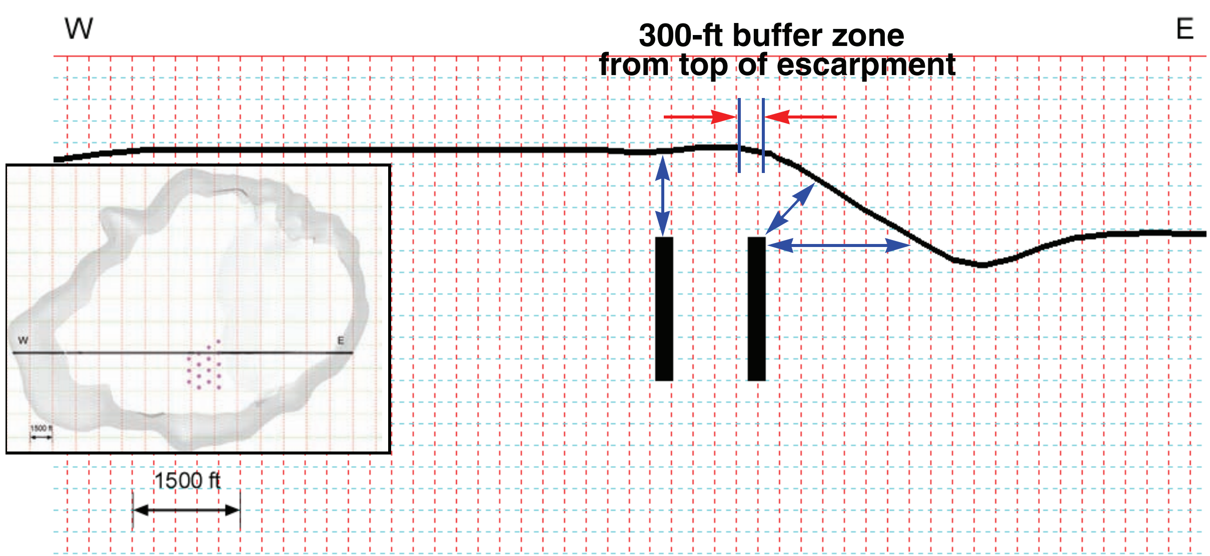


Figure 17. Cross section showing the geometric relationships of two of the proposed conceptual design SPR caverns to the top of salt surface, as displaced by the major structural break segmenting the Stratton Ridge salt dome. Inset map view of dome shows location of cross section. Vertical, horizontal, *and diagonal* offsets from this boundary (arrows) must all be considered in the design of the cavern field. Position of 300-ft buffer zone in this view is conceptual.

Project. Figure 15 also shows the lateral extent of a 300-ft buffer zone, inside the –1400-ft structure contour. Three hundred feet would most likely be the minimum acceptable offset of any cavern from this definition of the structural break between the two portions of the salt dome.

Figures 18 presents several views of the three dimensional model that capture the conceptual design expansion site. Figure 18, parts (b) and (c), are perspective views that attempt to portray more intuitively the relationship between the proposed cavern layout and the 300-ft buffer zone adjacent to the major structural break between the two parts of the Stratton Ridge salt stock.

Figure 19 displays a horizontal level plan through both the dome and caverns. The outline of the salt stock is mapped at both –2000 and –2500 ft. The grid displayed across the figure represents 500 ft intervals. It is clear that the proposed caverns are located well within the salt boundary presented in this model. However, it must be reiterated that there is a lack of direct well control defining this boundary.

Area and Volume of Salt Available for Development

The three-dimensional computer model of the Stratton Ridge salt dome has been used to extract estimates of the area and volume of salt potentially available for development of underground storage facilities. These estimates are provided for a number of different subsections of the salt stock. The estimated areas, which have been computed for the entire salt stock and for the region inside a 300-ft standoff distance from the edge of salt and from the structural boundary between the two portions of the dome, are presented in table 1. A similar set of volume computations are presented in table 2. These estimates do not include the area (or volume) currently occupied by existing caverns; the area occupied, or otherwise influenced, by existing brine and storage caverns at Stratton Ridge is known to be quite extensive.

The area of salt at the Stratton Ridge salt dome is approximately 3996 acres, at a (subsea) elevation of –2000 ft; this corresponds to about 4.8 square miles of salt, essentially all of which is located within the western two-thirds of the overall dome region (fig. 8). The area of salt increases with depth, as expected for a salt stock with outward dipping flanks. At –2500 ft, corresponding to the roof elevation of the proposed caverns, the area is some 3868 acres. This value does not consider the reduction indicated by any buffer zone adjacent to the structural break between the two parts of the dome. At –4500 ft, the sump level of the proposed caverns, the area increases to 5877 acres.

The volume of salt likewise increases with depth. The volume of the entire mapped dome, from the crest to 7000 ft subsea, is estimated to be roughly 37 cubic kilometers. The volume for the prime cavern interval, from –2500 to –4500 ft, is approximately 12.8 km^3. Other details of the volume estimates are in table 2.

Conclusions and Recommendations

The Stratton Ridge salt dome is a large salt diapir located only some 10 miles from the existing and active Bryan Mound SPR site near Freeport, Texas. This geologic technical assessment, which has been conducted using only existing and accessible geologic data, indicates that this dome may be considered a *viable*, if less-than-desirable, *candidate site* for an expansion facility for the U.S. Strategic Petroleum Reserve.

The salt dome at an elevation of 2000 ft, subsea, encompasses an area of approximately 4.8 square miles, *excluding the entire eastern one-third of the salt stock, which is judged unsuitable* for cavern development because of

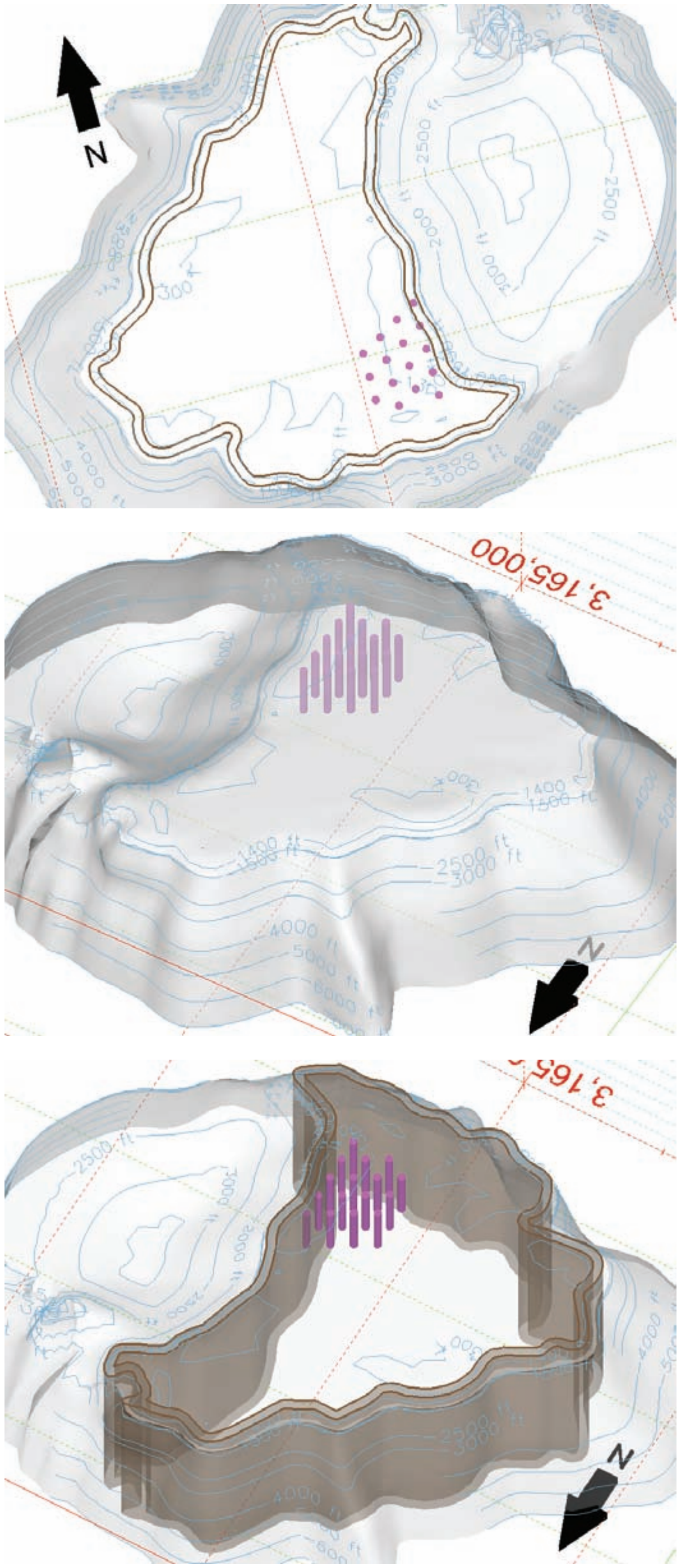


Figure 18. Partially transparent visualizations of a 3-D model showing the conceptual design cavern layout at the Stratton Ridge salt dome, with respect to the major structural break transecting the salt stock and the 300-ft buffer zone adjacent to that break. (a) Map view. (b) and (c) Perspective views from the northwest, without and with the 300-ft buffer zone, from part (a), projected vertically downward, respectively.

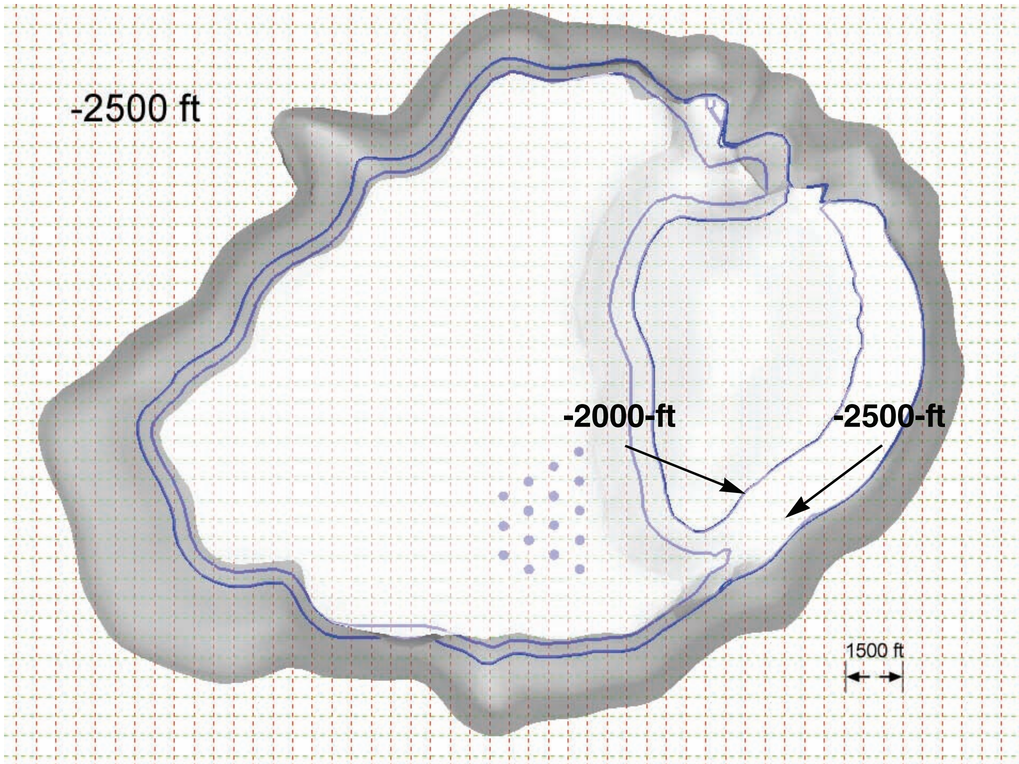


Figure 19. Horizontal level plan of the Stratton Ridge salt dome showing the relationship of the conceptual design SPR caverns to the edge of salt, at depths of approximately 2000 ft and 2500 ft. 2000 ft is near the top of the major structural break; -2500 ft is the roof elevation of the proposed caverns.

Table 1: Estimated Areal Extent of Salt Available for Development at the Stratton Ridge Salt Dome

Depth (ft)	Entire Dome			Inside 300-ft Buffer Zone		
	$ft^2 \times 10^6$	acres	km^2	$ft^2 \times 10^6$	acres	km^2
1400	103	2358	9.54	--	--	--
2000	135	3,096	12.5	115	2635	10.7
2500	169	3,868	15.7	134	3083	12.5
3000	207	4,750	19.2	176	4033	16.3
4000	246	5,654	22.9	226	5191	21.0
4500	256	5,877	23.8	236	5419	21.9

Table 2: Estimated Volume of Salt Available for Development at the Stratton Ridge Salt Dome

Depth Interval (ft)	Entire Dome		Inside 300-ft Buffer Zone	
	$ft^3 \times 10^9$	$m^3 \times 10^9$	$ft^3 \times 10^9$	$m^3 \times 10^9$
0–2500	157	4.43	103	2.92
0–4500	608	17.2	489	1.41
0–7000	1310	37.0	115	3.24
2500–4500[1]	451	12.8	395	1.12

[1] Potential cavern interval

its highly anomalous and probable complex structural character. At a depth of 4500 ft, subsea, the area of potentially suitable salt expands to roughly 9.2 square miles. The shallowest salt on the geologically acceptable western portion of the dome is documented at an elevation of –1272 ft; the shallowest caprock has been encountered at an elevation of –840 ft. Only minimal overhang of salt has been mapped. However, structural overhang is purportedly much more extensive (i.e., via proprietary 3-D seismic data unavailable to us) than can be documented reasonably using publically available well control.

Although the area and volume of salt available at Stratton Ridge are more than sufficient, in a general sense, this dome has been intensively developed — in the most desirable central portion — for both brine-supply and storage caverns. Expansion caverns cannot be located within this region of major development. Contiguous acreage suitable for development of SPR expansion caverns may be difficult to aggregate, the right of eminent domain notwithstanding. Acquisition of existing brine caverns is strongly not recommended, as operational problems, including product releases, have been widely reported. Brining operations are believed to have been largely uncontrolled, resulting in undesirable cavern shapes and sizes.

Furthermore, the geometric configuration of the top-of-salt and top-of-caprock surfaces suggests that the Stratton Ridge salt stock consists of a modestly large number of individual salt spines or spine complexes. At least three large spine complexes appear to be present in the western portion of the salt dome. These complexes may be subdivided into as many as eight smaller spines. The near-certain existence of boundary shear zones between these spines and spine complexes may pose significant construction and/or operational difficulties for cavern development. Numerous instances of anomalous cavern behavior at existing caverns are widely described within the storage industry; significantly fewer instances have been formally reported in published literature or to Texas regulatory authorities.

The current conceptual design for an expansion SPR cavern field is unacceptable, according to this new reinterpretation of salt dome geology. The easternmost set of caverns are located within a 300-ft buffer zone of the major boundary shear zone, fault, or other structural feature of indeterminate origin, that transects the salt stock and divides it into an elevated western part and a depressed eastern part. In places, the distance from this structural boundary to the design-basis caverns is as little as 150 ft. A 300-ft distance from this boundary is likely to be the minimum acceptable standoff from both a geologic and a regulatory perspective. Repositioning of the proposed cavern field is possible, but the reconfiguration would be subject to limitations related to land-parcel boundaries and other existing infrastructure (e.g., the rail line shown to the west of the conceptual design caverns in figure 14) and topographic constraints.

Prior to full-scale commitment to an SPR expansion site at the Stratton Ridge salt dome, a more detailed geological characterization study of this site should be undertaken. In addition to the interpretation of well logs, scout tickets, and well-completion cards that has formed the basis of the current investigation, the records of the Railroad Commission of Texas should be searched for publicly available proceedings-of-record for previous permit applications, off-normal "event" reporting, and other documents that may reasonably bear on the geology of the salt stock, the caprock, and on-going geologic processes that might affect potential SPR cavern operations.

The large body of extant seismic data should be examined, and selected surveys that bear on (a) the position of the relevant salt flanks and (b) the major structural discontinuity segmenting the dome should be acquired, reprocessed, and reinterpreted. A relatively recent 3-D seismic survey exists; these data should be licensed, reprocessed if appropriate, and reinterpreted if at all possible. This survey, or a similar 3-D survey in critical locations, offers the best possibility for reducing the likely impact of structural complexity at this site. Information from the recently completed Freeport LNG core hole should be obtained, if possible.

References

DOE (Department of Energy). 1991. *Candidate Storage Sites for the 250 Million Barrel Increment to the Strategic Petroleum Reserve*. Strategic Petroleum Reserve Project Management Office, New Orleans, La., February 1991.

Neal, J.T., Magorian, T.R., Lamb, D.W., Xiao, J., Byrne, K. 1991. *Preliminary Geological Site Characterization for Strategic Petroleum Reserve (SPR) Expansion Candidate Sites, Stratton Ridge Salt Dome, Texas*. Sandia National Laboratories, Albuquerque, N. Mex., March 15, 1991. 10 p.

PBESS (PB Energy Storage Services, Inc.). 2006. *Proposed Stratton Ridge SPR Facility, 160 MMB Crude Oil Storage Facility, Vicinity Map*. AutoCAD drawing file 50535A-C-SR001, March 24, 2006. PB Energy Storage Services, Inc., Houston, Tex.

Appendix A. List of Oil, Gas, and Other Wells Used to Characterize the Stratton Ridge Salt Dome

This page intentionally left blank.

Table A-1: Locations and tops of caprock and salt for wells used to model the Stratton Ridge salt dome

[Top of caprock and top of salt are elevations; all coordinate values, depths, and elevations in feet. Short API numbers are prefixed by state code (42) and county code (039), and suffixed by sidetrack code (00). Abstract is the Texas land-survey abstract number]

Easting	Northing	Short API	Operator	Lease	Well	TD	Abstract	Top Caprock	Top Salt	Control
3175936.2	461426.6	04294	E. Cockrell Jr.	Chilton, M.	1	4764	145	--	-4736	Indirect
3174773.7	461597.3	04296	E. Cockrell	Chilton, M.	3	2536	145	--	-2352	Direct
3176913.7	459114.7	04298	E. Cockrell	Chilton, M.	5	6142	145	--	-6119	Indirect
3176463.7	459089.7	04299	E. Cockrell	Chilton, M.	6	5275	145	--	-5247	Indirect
3175277.4	458797.7	04301	E. Cockrell	Chilton, M.	8	2277	145	--	-2249	Indirect
3174834.0	462017.5	04302	Rycade Oil	Seaburn	1	2682	145	-2266	-2365	Direct
3176769.7	461856.6	04303	Rycade Oil Corp.	Seaburn	2	7636	145	--	-7608	Indirect
3175862.7	461831.7	04304	Amerada-Rycade	Seaburn	3	5580	145	-4804	--	Direct
3176464.5	461603.2	04306	Amerada-Rycade	Seaburn	5	7202	145	--	-7174	Indirect
3175706.8	461808.6	04308	Newman Bros.-Alaska Stmshp.	Seaburn Heirs	2	4420	145	-4399	-4501	Direct
3175865.2	462057.3	04309	Thompsons Drlg. Co.	Seaburn Est.	1	4770	145	--	-4742	Indirect
3174734.2	463971.4	04310	Adams & Haggerty	Chilton, M.	1G	5013	145	--	-4722	Direct
3173095.0	467517.4	04312	Sterling	Shanks, W.	1	9267	153	--	-9239	Indirect
3172108.6	467682.9	04314	E. Cockrell	Hudgins, E.	1	7604	153	--	-7576	Indirect
3167712.3	466621.2	04319	E. Cockrell	Herrick-Cannon Unit	1	4884	196	--	-4835	Direct
3168218.6	466477.0	04320	E. Cockrell Jr.	Cannan, G.	1	4762	196	--	-4690	Direct
3169005.7	466756.3	04321	E. Cockrell	Doehring, P.	1	5971	196	--	-5943	Indirect
3169679.0	466380.8	04322	E. Cockrell	Harris & Abercrombie	1	5261	196	--	-5233	Indirect
3169141.1	466207.6	04323	Pure Oil Co.	Armstrong	1	4421	196	--	-4393	Indirect
3169853.9	466102.6	04326	Sterling O&R	Kramer	1	4960	196	-4587	-4619	Direct
3170242.8	466136.6	04327	Empire O&F Co.	Wilson	1	4672	196	--	-4648	Indirect
3167977.2	464487.0	04331	Freeport Sulphur	Tolar & Dannebaum	4	1326	66	-1210	-1291	Direct
3169688.1	465275.3	04337	Freeport Sulphur	Tolar & Dannebaum	10	3255	66	--	-2605	Direct
3169282.9	465251.7	04340	Freeport Sulphur	Tolar & Dannebaum	13	1369	66	-1287	--	Direct
3168735.3	465591.0	04342	Freeport Sulphur	Tolar & Dannebaum	15	1326	66	-1297	--	Direct
3168646.9	465148.1	04344	Freeport Sulphur	Tolar & Dannenbaum	17	1352	66	-1282	-1537	Direct
3168244.8	465641.2	04345	Freeport Sulphur	Tolar & Dannebaum	18	1365	66	-1285	-1333	Direct
3168880.6	465850.2	04346	Stratton Ridge Oil	Tolar & Dannenbaum	1	1329	66	--	-1301	Indirect
3169350.5	465031.9	04349	Werner Royalty	Tolar & Dannebaum	3	1342	66	-1281	-1331	Direct
3167104.4	465416.4	04351	Currie Oil Co.	Tolar & Dannebaum	2	1345	66	-1312	-1362	Direct

Table A-1: Locations and tops of caprock and salt for wells used to model the Stratton Ridge salt dome (Continued)

[Top of caprock and top of salt are elevations; all coordinate values, depths, and elevations in feet. Short API numbers are prefixed by state code (42) and county code (039), and suffixed by sidetrack code (00). Abstract is the Texas land-survey abstract number]

Easting	Northing	Short API	Operator	Lease	Well	TD	Abstract	Top Caprock	Top Salt	Control
3165950.3	465529.4	04353	Brazos O&G Co.	Tolar, G.	1	1375	66	-1305	-1338	Direct
3166899.5	463485.7	04357	C. C. Cannon	Strattton, M.	1	930	66	-882	--	Direct
3173569.8	459526.1	04360	E. Cockrell Oil Co.	Seaburn Est.	2	5033	66	--	-5005	Indirect
3171138.4	465604.5	04364	E. Cockrell	Seaburn Heirs	5	4640	66	--	-4598	Direct
3170932.0	465765.3	04365	E. Cockrell	Seaburn Heirs	6	4663	66	--	-4635	Indirect
3171927.1	465931.2	04367	E. Cockrell	Seaburn Heirs	8	6226	66	--	-6183	Direct
3172264.7	465359.7	04369	E. Cockrell	Seaburn Heirs	10	4916	66	--	-4888	Indirect
3172432.4	465106.7	04370	E. Cockrell	Seaburn Heirs	11	4142	66	--	-4114	Indirect
3172003.4	464824.1	04371	E. Cockrell	Seaburn Heirs	1C	4254	66	--	-4115	Direct
3172590.3	464762.5	04372	E. Cockrell	Seaburn Heirs	2C	4879	66	--	-4449	Indirect
3173382.5	464470.9	04373	E. Cockrell	Seaburn Heirs	3C	4795	66	--	-4767	Indirect
3171652.5	465922.5	04374	Freeport Sulphur	Seaburn	1	5058	66	--	-4737	Direct
3171152.6	465048.4	04375	Freeport Sulphur	Seaburn	2	2540	66	-2352	-2445	Direct
3172952.1	463824.4	04378	Amerada-Rycade	Bowers	1	4755	66	-2337	-3412	Direct
3170673.3	462698.1	04380	Humble-Farish	Seaburn	1	2096	66	--	-1887	Direct
3171239.9	458288.9	04382	Bowman	Seaburn	1	3760	66	--	-3697	Direct
3171401.5	459865.4	04383	Humble	Seaburn	1B	3635	66	--	-3607	Direct
3170028.1	452481.8	04384	Humble	Seaburn	2B	1799	66	--	-1576	Direct
3171881.9	457388.7	04385	Humble	Seaburn	3B	3204	66	--	-3176	Indirect
3167881.5	457223.4	04386	Humble-Shell	Seaburn	1	1686	66	--	-1658	Indirect
3168373.9	455689.2	04387	Humble-Shell	Seaburn	2	1955	66	--	-1927	Indirect
3169580.7	454413.8	04388	Humble-Shell	Seaburn	3	2522	66	--	-2496	Indirect
3162270.8	454258.4	04390	Humble-Shell	Seaburn	5	1121	66	-1017	--	Direct
3160421.0	455346.7	04389	Humble-Shell	Seaburn	4	1400	66	--	-1372	Indirect
3171244.8	457419.7	04392	Humble-Shell	Seaburn	7	3499	66	--	-3471	Indirect
3164110.6	460361.3	04393	Union Sulphur	Brock	1	1231	66	-861	--	Direct
3165143.4	462914.3	04394	Castell Oil Co.	Storrie, R.	1	1314	66	-854	--	Direct
3161842.4	461862.1	04398	P.H. Pewitt	Storrie, R.	2A	1386	66	-1092	-1348	Direct
3160001.4	464329.3	04399	Humble	Shea & Storrie	1	4086	66	--	-4058	Indirect
3159101.0	461620.5	04400	E. Cockrell	Brock, F.	1	4236	66	--	-4208	Indirect

Table A-1: Locations and tops of caprock and salt for wells used to model the Stratton Ridge salt dome (Continued)

[Top of caprock and top of salt are elevations; all coordinate values, depths, and elevations in feet. Short API numbers are prefixed by state code (42) and county code (039), and suffixed by sidetrack code (00). Abstract is the Texas land-survey abstract number]

Easting	Northing	Short API	Operator	Lease	Well	TD	Abstract	Top Caprock	Top Salt	Control
3158877.6	462021.0	04401	E. Cockrell	Brock, F.	2	6866	66	--	-6838	Indirect
3157311.9	462729.0	04402	E. Cockrell	Brock, F.	3	8749	66	--	-8721	Indirect
3157950.5	463469.0	04403	E. Cockrell	Brock, F.	4	9701	66	--	-9673	Indirect
3160483.3	465071.8	04404	E.L. Cockrell	Brock, F.	5	7219	66	--	-7191	Indirect
3155248.8	456783.3	04405	E.L. Cockrell	Brock, F.A.	6	4584	66	--	-3947	Direct
3154644.2	456691.8	04406	Ernest Cockrell	Brock, F.A.	7	5174	66	--	-4722	Direct
3158580.2	455020.4	04407	Freeport Sulphur	Stratton	1	1336	66	-1198	-1296	Direct
3160221.2	452619.7	04408	Freeport Sulphur	Seaburn	1	1896	66	--	-1868	Indirect
3165932.0	455671.1	04412	Freeport Sulphur	Seaburn	4	990	66	-857	--	Direct
3162793.2	451546.5	04413	Freeport Sulphur	Tolar	1	1457	66	-1056	-1274	Direct
3159820.8	460158.7	04414	Humble	Brock	1	1471	66	-1274	-1283	Direct
3174893.1	453838.5	04423	E. Cockrell	Bowers, A.	9	5506	66	--	-5478	Indirect
3173398.6	453784.2	04426	E. Cockrell	A. Bowers-04049	12	4590	66	--	-4863	Indirect
3172122.1	452180.0	04434	E. Cockrell	E. Seaburn Heirs	6S	4782	66	--	-4652	Direct
3169424.0	450331.2	04436	E. Cockrell	Bowers, A.	2A	5836	21	--	-5838	Indirect
3168375.5	449811.0	04440	Texaco Inc.	Mcvea, M.	2	6200	21	--	-6172	Indirect
3168265.6	450156.8	04441	Texaco Inc.	Mcvea, M.	3	5013	21	--	-4985	Indirect
3165458.2	449850.8	04442	E. Cockrell	Brock, F.	1A	3662	21	--	-3622	Direct
3166180.7	449855.2	04444	E. Cockrell	Brock, F.	3A	4877	21	--	-4849	Indirect
3166331.9	449416.1	04446	E. Cockrell	Brock, F.	5A	5765	21	--	-6722	Indirect
3167733.2	449900.0	04450	E. Cockrell	Brock, F.	9A	5700	21	--	-5672	Indirect
3165559.1	449999.5	04452	Gulf Prod. Co., Inc.	Perry	2	3761	21	--	-3723	Direct
3165169.0	449281.6	04458	The Texas Co.	Perry, H.	1	5755	21	--	-5727	Indirect
3155979.9	452269.9	04459	Brazos O&G Co.	Dow Chemical Co.-Stevens	1	5357	66	--	-5260	Direct
3155423.5	451754.4	04460	Brazos O&G. Co.	Dow Chemical Fee	2	6211	66	--	-6173	Direct
3155773.0	457508.8	04461	Humble	Brock	2	2904	66	--	-2876	Indirect
3157352.5	458219.7	04462	Empire O&G Co.	Brock, C.	1	2240	66	--	-2212	Indirect
3156330.2	458199.0	04463	Empire O&G Co.	Brock	2	3711	66	--	-3498	Direct
3155531.0	458199.7	04464	Empire O&G Co.	Brock	3	4910	66	--	-4482	Indirect
3165399.9	451002.1	04854	E. Cockrell	Brock, F.	10A	2687	66	--	-2659	Indirect

Table A-1: Locations and tops of caprock and salt for wells used to model the Stratton Ridge salt dome (Continued)

[Top of caprock and top of salt are elevations; all coordinate values, depths, and elevations in feet. Short API numbers are prefixed by state code (42) and county code (039), and suffixed by sidetrack code (00). Abstract is the Texas land-survey abstract number]

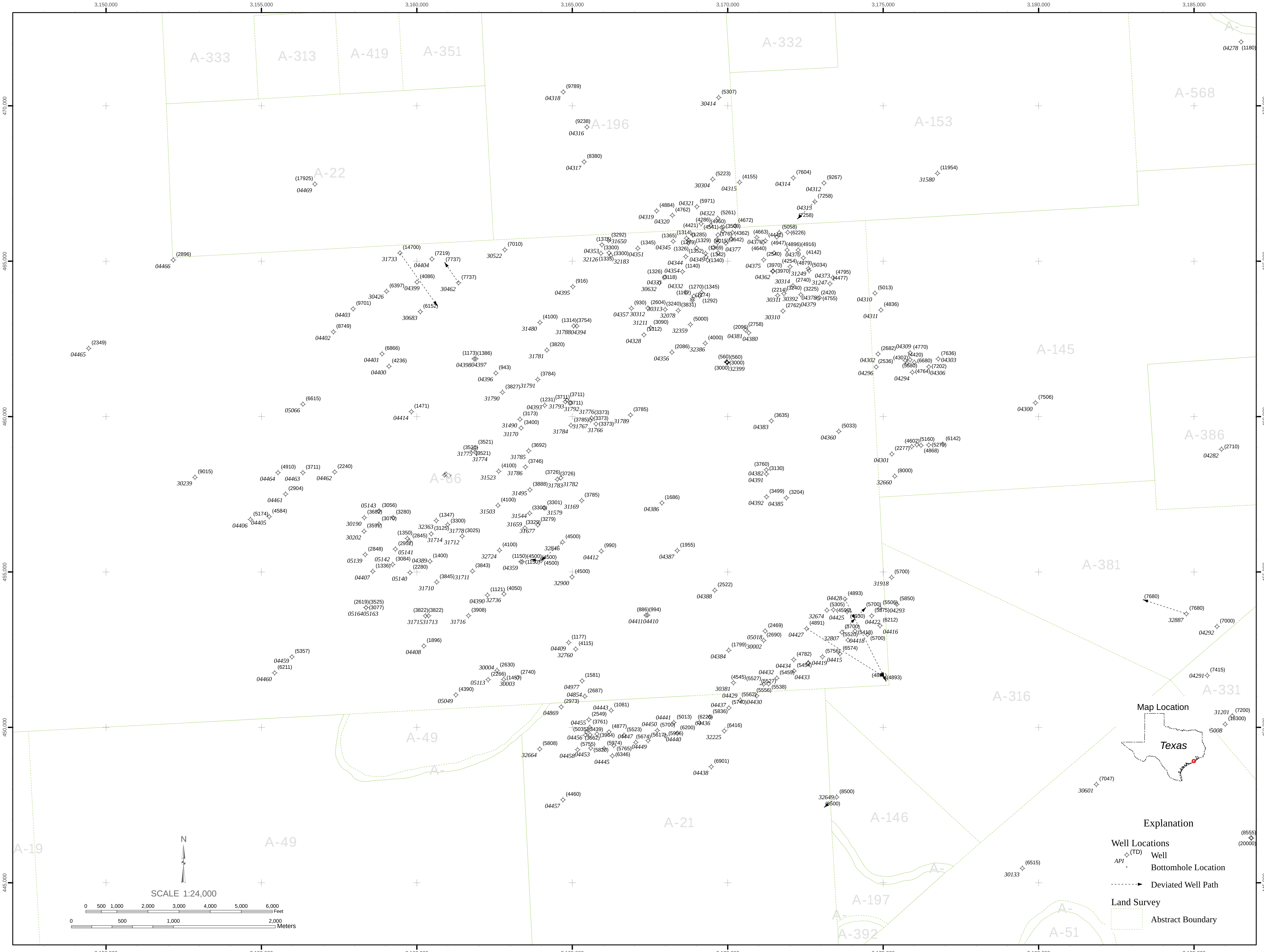
Easting	Northing	Short API	Operator	Lease	Well	TD	Abstract	Top Caprock	Top Salt	Control
3164643.2	450662.0	04869	E. Cockrell	Brock, F.	11A	2973	21	--	-2945	Direct
3165314.1	451497.8	04977	Cockrell E Jr	Brock F A	12	1581	66	--	-1553	Indirect
3171201.2	453100.5	05018	Cockrell Corp	Seaburn	110 S	2469	66	--	-2441	Indirect
3161251.6	451047.5	05049	Cockrell Corp	Seaburn Heirs	1 R	4390	66	--	-4362	Indirect
3156332.4	460399.8	05066	Continental	Brock Fred A	1	6615	66	--	-6587	Indirect
3162291.5	451538.2	05113	Cockrell Corp.	Seaburn Heirs	2R	2266	66	--	-2238	Indirect
3158336.4	455562.1	05139	Dow Chemical Co.	Stevens Tract	2	2848	66	-1115	-1316	Direct
3159306.0	455737.7	05141	Dow Chemical Co.	Stevens Tract	5	2952	66	-1041	-1309	Direct
3159222.2	455244.0	05142	Dow Chemical Co.	Stevens Tract	4	3084	66	-1133	-1301	Direct
3158781.9	456969.1	05143	Dow Chemical Co.	Stevens Tract	11	3056	66	-1213	-1308	Direct
3158363.7	453857.0	05163	Dow Chemical Co.	Stevens	10	2619	66	-949	-1312	Direct
3171153.1	452800.7	30002	Cockrell Corp.	Seaburn	115S	2690	66	--	-2668	Indirect
3163242.3	451600.5	30003	Cockrell Corp.	Seaburn Heirs	112R	2740	66	--	-2712	Indirect
3158776.1	456536.1	30183	Dow Chemical Co.	Stevens Tract	13	3070	66	-1254	-1302	Direct
3158309.1	456750.7	30190	Dow Chemical Co.	Stevens Tract	14	3682	66	-1239	-1307	Direct
3171803.6	463959.4	30311	Fenix Scisson, Inc.	Amoco Chemicals	2E	3240	66	-927	-1297	Direct
3167429.7	463495.0	30312	Fenix Scisson, Inc.	Amoco Chemicals	1B	2604	66	-995	-1306	Direct
3167987.4	463446.9	30313	Fenix Scisson, Inc.	Amoco Chemicals	1E	3240	66	-944	-1306	Direct
3172096.1	464212.3	30314	Fenix Scisson, Inc.	Amoco Chemicals	1EP	2740	66	-871	-1298	Direct
3170182.2	451439.0	30381	Cockrell Corp.	Amoco Chemicals	7S	4545	66	--	-4517	Indirect
3172348.1	463925.5	30392	Fenix & Scisson Inc.	Amoco Chemicals	2EP	3225	66	-927	-1301	Direct
3159023.0	464029.7	30426	Texaco Inc.	Brock, J.	1	6397	66	--	-8256	Indirect
3160107.7	463375.9	30683	Texaco Inc.	Brock, J.	3	6152	66	--	-6144	Indirect
3163353.3	459635.7	31170	Dow Chemical Co.	Brock	37	3400	66	-950	-1304	Direct
3167516.7	462861.1	31211	Fenix & Scisson, Inc.	Amoco Chemicals	2P	3090	66	--	-1290	Direct
3173286.2	464278.7	31247	Cockrell Corp.	Seaburn	2D	4477	66	--	-4449	Indirect
3163957.1	463030.1	31480	Dow Chemical Co.	Brock 345414	40	4100	66	-1008	-1315	Direct
3163627.4	456890.6	31544	Dow Chemical Co.	Dow Fee	6	3300	66	-882	-1302	Direct
3164095.4	457054.3	31579	Dow Chemical Co.	Dow Fee	9	3301	66	-872	-1301	Direct
3166160.0	465670.6	31650	Seminole Pipeline Co.	Amoco Chemicals	2	3292	66	--	-1443	Direct

Table A-1: Locations and tops of caprock and salt for wells used to model the Stratton Ridge salt dome (Continued)

[Top of caprock and top of salt are elevations; all coordinate values, depths, and elevations in feet. Short API numbers are prefixed by state code (42) and county code (039), and suffixed by sidetrack code (00). Abstract is the Texas land-survey abstract number]

Easting	Northing	Short API	Operator	Lease	Well	TD	Abstract	Top Caprock	Top Salt	Control
3161658.4	453595.5	31716	Dow Chemical Co.	Dow Fee	7	3908	66	-1195	-1299	Direct
3159454.5	465265.4	31733	Energy Devl., Of N.J.	Brock	1	14700	66	--	-14700	Indirect
3165759.5	459765.2	31766	Dow Chemical Co.	Brock	5A	3373	66	-863	-1306	Direct
3165586.3	459883.5	31767	Dow Chemical Co.	Brock	5B	3373	66	-840	-1337	Direct
3160891.0	458122.2	31770	Dow Chemical Co.	Brock	12	4018	66	-1222	-1304	Direct
3161026.1	458097.3	31772	Dow Chemical Co.	Brock	12B	3560	66	-1050	-1304	Direct
3161797.0	458903.4	31773	Dow Chemical Co.	Brock	13	3521	66	-1072	-1299	Direct
3161904.8	458826.7	31774	Dow Chemical Co.	Brock	13A	3521	66	-1052	-1307	Direct
3161877.0	459004.1	31775	Dow Chemical Co.	Brock	13B	3521	66	-1019	-1304	Direct
3164179.8	462142.2	31781	Dow Chemical Co.	Brock	26A	3820	66	-1025	-1300	Direct
3164627.7	458027.6	31782	Dow Chemical Co.	Brock	25B	3726	66	-882	-1303	Direct
3164517.2	457984.1	31783	Dow Chemical Co.	Brock	25A	3726	66	--	-1311	Direct
3163593.5	458901.1	31785	Dow Chemical Co.	Brock	15	3692	66	-1118	-1297	Direct
3163491.5	458381.4	31786	Dow Chemical Co.	Brock	16	3746	66	-1102	-1303	Direct
3166869.3	460050.9	31789	Dow Chemical Co.	Brock	30A	3785	66	-1047	-1301	Direct
3162751.8	460780.9	31790	Dow Chemical Co.	Brock	32A	3827	66	-921	-1304	Direct
3163886.5	461194.6	31791	Dow Chemical Co.	Brock	27A	3784	66	-975	-1302	Direct
3164942.3	460445.4	31792	Dow Chemical Co.	Brock	17B	3711	66	-1139	-1293	Direct
3164824.6	460529.1	31793	Dow Chemical Co.	Brock	17A	3711	66	-1084	-1295	Direct
3159761.9	455984.6	31802	Dow Chemical Co.	Stevens Tract	1A	2845	66	-937	-1301	Direct
3159233.0	456750.3	31808	Dow Chemical Co.	Stevens Tract	12	3280	66	-1106	-1301	Direct
3175268.0	454828.8	31918	Texaco Inc.	J. Loggins Fee	2	5700	316	--	-5672	Indirect
3169274.4	462359.6	32386	Amoco Chemical Co.	Amoco Chemical Co.	3NG	4000	66	--	-3972	Indirect
3169977.6	461745.0	32398	Amoco Chemical Co.	Amoco Chemical Co.	3ST	560	66	--	-2972	Indirect
3176079.9	459095.8	32661	Neumin Production Co.	Dow	2B	5160	145	--	-2594	Direct
3162800.4	454293.1	32736	Dow Chemical Co.	Dow Fee	13	4050	66	--	-1282	Direct
3166660.5	449746.5	32786	Rimco Prod Co Inc	Dow Chemical Co.	1	5523	21	--	-5495	Indirect

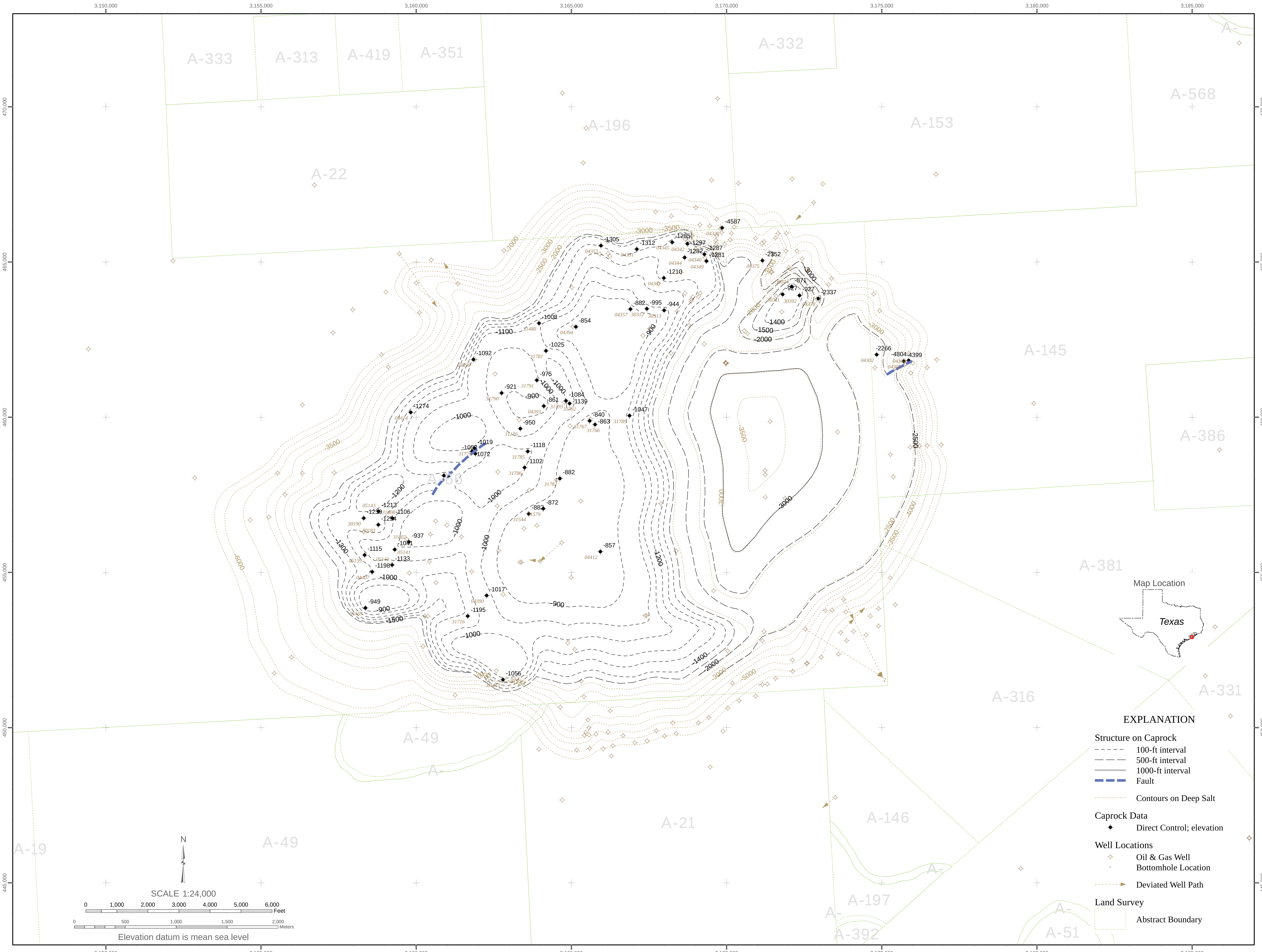
This page intentionally left blank.



Projection and grid ticks : Texas state coordinate system, south-central zone, in feet (Lambert conformal conic)
North American Datum of 1927

WELL LOCATION MAP FOR THE STRATTON RIDGE SALT DOME, TEXAS

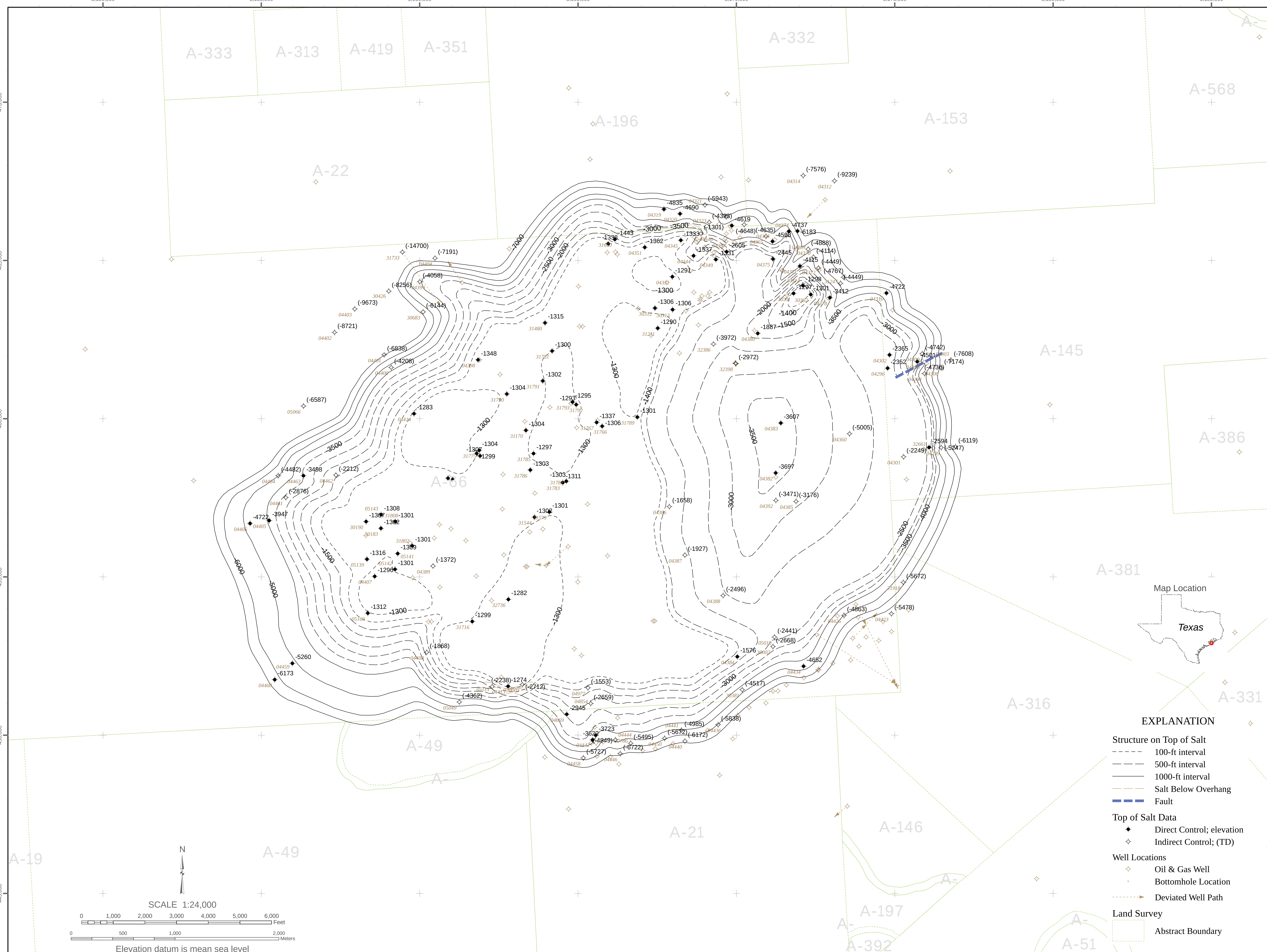
SAND2006-7159 November 2006



Projection and grid ticks : Texas state coordinate system, south-central zone, in feet (Lambert conformal conic)
North American Datum of 1927

STRUCTURE ON TOP OF CAPROCK (AND DEEP SALT) AT THE STRATTON RIDGE SALT DOME, TEXAS

SAND2006-7159 November 2006



SAND2006-7159 November 2006

Projection and grid ticks: Texas state coordinate system, south-central zone, in feet (Lambert conformal conic)
North American Datum of 1927

STRUCTURE ON TOP OF SALT AT THE STRATTON RIDGE SALT DOME, TEXAS

DISTRIBUTION:

U.S. Department of Energy (via CD-R only)
Strategic Petroleum Reserve Project Management Office
900 Commerce Road East
New Orleans, LA 70123

U.S. Department of Energy (3)
Strategic Petroleum Reserve Program Office
1000 Independence Avenue, SW
Washington, D.C. 20585
Attn: D. Johnson, FE-421

Sandia Internal:

MS 1002	S. Roehrig, 6300
MS 1104	Margie Tatro, 6200
MS 0706	D.J. Borns, 6312
MS 0706	B.L. Ehgartner, 6312
MS 0706	B.L. Levin, 6312
MS 0706	Anna S. Lord, 6312 (5)
MS 0706	C.A. Rautman, 6312 (5)
MS 0706	A.R. Sattler, 6312
MS 0776	J.S. Stein, 6782 (5)
MS 0706	S. Wallace, 6312 for SPR library
MS 0735	R.E. Finley, 6313
MS 0750	T.E. Hinkebein, 6316
MS 9018	Central Tech. Files, 8945-1
MS 0899	Technical Library, 9616 (2)