March, 2001

Qualitative appraisal of oil, gas, coal, and coal-bed methane in 21 U. S. National Monuments established or expanded between 1996-2001.

USGS Central Region Assessment Team

Introduction

Twenty-One National Monuments were established or expanded in the United States between 1996 and 2001 (Table 1). The U.S. Geological Survey was requested by the staff of the Subcommittee on National Parks, Recreation, and Public Lands of the House Resources Committee to provide a rapid, qualitative appraisal of the potential for oil, gas, and coal resources beneath these National Monuments.

Most of the new or expanded National Monuments are located in the western states; California (5), Arizona (5), Idaho (2), Montana (2), Washington (1), Oregon (1), Utah (1), Colorado (1), and New Mexico (1), but two are in the U.S. Virgin Islands (Table 1). The new or expanded National Monuments vary in size from nearly 2 million acres (Grand Staircase-Escalante National Monument, Utah) to 51 acres (Pompey's Pillar National Monument, Montana).

Methodology

For each National Monument, we searched for the most recent, accurate boundary, most of which were located on Bureau of Land Management (BLM) websites devoted to the new or expanded National Monuments. The boundaries of the National Monuments varied from detailed to general in nature. The boundary data were added to an ArcView project that included geology, oil and gas wells, oil and gas fields, oil and gas play boundaries defined for the 1995 National Oil and Gas Assessment, and coal fields mapped during the National Coal Assessment. Regional geologic experts were assembled for the appraisal meeting, which was held in Denver, Colorado on February 21, 2001. The geology and resource potential of each National Monument was discussed in detail, and consensus was reached on 1) the probability of occurrence and scale of the oil and gas resource, and 2) the probability of occurrence of coal and coal-bed methane.

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Table 1. National Monuments expanded or declared during 1996-2001

Date	National Monument	State
9/18/96	Grand Staircase-Escalante National Monument	Utah
1/11/00	Grand Canyon-Parashant National Monument	Arizona
1/11/00	Agua Fria National Monument	Arizona
1/11/00	California Coastal National Monument	California
1/22/00	Pinnacles National Monument	California
4/15/00	Giant Sequoia National Monument	California
6/9/00	Hanford Reach National Monument	Washington
6/9/00	Cascade Siskiyou National Monument	Oregon
6/9/00	Ironwood Forest National Monument	Arizona
6/9/00	Canyons of the Ancients National Monument	Colorado
10/25/00	Santa Rosa & San Jacinto Mountains National Monument	California
11/10/00	Craters of the Moon National Monument	Idaho
11/10/00	Vermillion Cliffs National Monument	Arizona
1/17/01	Upper Missouri River Breaks National Monument	Montana
1/17/01	Pompey's Pillar National Monument	Montana
1/17/01	Kasha-Katuwe Tent Rocks National Monument	New Mexico
1/17/01	Carrizo Plain National Monument	California
1/17/01	Sonoran Desert National Monument	Arizona
1/17/01	Minidoka Internment National Monument	Idaho
1/17/01	Buck Island Reef National Monument	Virgin Islands
1/17/01	Virgin Islands Coral Reef National Monument	Virgin Islands

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Given the time constraints imposed upon this task, we could not conduct a quantitative assessment of 21 National Monuments. Rather, for oil and gas we used the published geology of each area and the assessment results from the 1995 USGS National Assessment (Gautier and others, 1995) as a qualitative guide to the potential for each area, where applicable. For coal in the Colorado Plateau we used the results of the 2000 USGS National Coal Assessment (Kirschbaum and others, 2000), as well as the combined experience of the personnel involved in coal assessment of the U.S.

For the determination of the probability of oil and/or gas occurrence, we assessed the qualitative probability that the parcel of land has undiscovered oil and/or gas resources, and then we assessed the qualitative scale of the resource. For probability of oil and gas we used the terms very low, low, medium, and high, and for resource scale we used very small, small, medium, and large. We realize that the use of such terms does not convey a quantitative assessment, but this approach can be used as a first approximation to the relative probability and scale of resources beneath each National Monument. We discussed the probability for both conventional and continuous oil and gas resources in each National Monument.

For oil and gas accumulations to form, several elements or processes of a *petroleum system* must coincide or occur in series. There must be adequate organic-bearing hydrocarbon *source rocks* that are heated sufficiently to *generate* hydrocarbons. The hydrocarbon fluids generated in the source rock must be *expulsed* from the rock and must *migrate* into *reservoirs* that exist in *traps*. Traps, which can range from structural to stratigraphic, must provide a sufficient *seal* to trap and preserve the hydrocarbons. The appraisal of the oil and gas potential of an area involves the examination of each of these petroleum system elements. If an area already has oil and gas accumulations, the probability of additional accumulations may involve more certainty than an area that does not have discovered hydrocarbon accumulations at present.

For the determination of the occurrence of coal and coal-bed methane resource, we used the following terms; very low (thin coals in discontinuous beds), low (thick coals in discontinuous beds) and high (thick coals in continuous beds). We recognized that there may not be “mineable” coal in any given area, but there may be potential for coal-bed methane in the same area.

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The assessment team for this task included L. Tennyson, J.W. Schmoker, C.J. Schenk, T. Rohrbacher, S. Roberts, R.M. Pollastro, V.F. Nuccio, T. Klett, M. Kirschbaum, R. Dubiel, R.R. Charpentier, and T.S Ahlbrandt. C. Anderson and S. Weiler provided the GIS data compilation that allowed us to complete this assessment. W. Husband created the graphics for this report.

Summary of Appraisal Results

A summary of the qualitative appraisal results for the 21 National Monuments is provided in Table 2. Detailed discussions of these results are provided in a later section of this report.

Five of the National Monuments were appraised as having no potential for oil, gas, coal, or coal-bed gas; Agua Fria National Monument, Arizona; Giant Sequoia National Monument, California; Santa Rosa and San Jacinto Mountains National Monument, California; Buck Island Reef National Monument, St. Croix; and Virgin Islands Coral Reef National Monument, St. Johns. In these Monuments either there were no sedimentary rocks present in the subsurface, or hydrocarbon source rocks were not present in the subsurface.

Eleven of the National Monuments were appraised as having very low or low probability for the occurrence of oil and gas; Cascade-Siskiyou National Monument, Oregon; Craters of the Moon National Monument, Idaho; Grand Canyon-Parashant National Monument, Arizona; Grand Staircase-Escalante National Monument, Utah; Ironwood Forest National Monument, Arizona; Kasha-Katuwe Tent Rocks National Monument, New Mexico; Minidoka Internment National Monument, Idaho; Pinnacles National Monument, California; Pompey's Pillar National Monument, Montana; Sonoran Desert National Monument, Arizona; and Vermilion Cliffs National Monument, Arizona. For the most part the oil and gas plays underlying or in the vicinity of these Monuments were largely speculative.

Five of the National Monument were appraised as having moderate to high probability for the occurrence of oil and gas resources; California Coastal National Monument, California; Canyons of the Ancients National Monument, Colorado; Carrizo Plain National Monument, California; Hanford Reach National Monument, Washington; and Upper Missouri River

Breaks National Monument, Montana. For the most part these National Monuments are in areas of established oil and gas production (such as Canyons of the Ancients National Monument), or where well tests have demonstrated that a viable petroleum system exists in the subsurface (Hanford Reach National Monument).

For coal and coal-bed gas, the only area appraised to have high probability for coal and coal-bed gas is Grand Staircase-Escalante National Monument, Utah, largely due to the thickness and lateral extent of the coals. Three areas were appraised as having low to very low probability for coal or coal-bed methane, including Canyons of the Ancients National Monument, Upper Missouri River Breaks National Monument, and Pompey's Pillar National Monument. In the case of Pompey's Pillar, the extremely limited size of the Monument (51 acres) suggests that the resource, although cited as very low, is actually vanishingly low.

These appraisals were intended as a rapid approach to determining the relative scale of the probability and volume of resource that may be present in the subsurface of the 21 National Monuments based on the petroleum geology and coal geology. At no time did we discuss whether the lands of the National Monuments were available or off limits to resource extraction.

Table 2.

National Monuments established or expanded, 1996-2001
Oil, Gas, and Coal Appraisal Summary

[The qualitative appraisal for oil and gas used the following terms for probability of oil and gas occurrence; very low, low, moderate, and high; for potential volumes given the probability of occurrence the following terms were used; very small, small, medium, and large. The appraisal of coal and coal-bed gas was for the probability of the presence of resource using the following relative terms; high (thick coals, continuous beds), low (thick coals, discontinuous beds), and very low (thin coals, discontinuous beds). The results in this table represent a consensus from the assembled group of geologic experts.]

	Oil		Gas		Coal	Coalbed Gas
	Probability	Volume	Probability	Volume		
Agua Fria National Monument, Arizona	none	none	none	none	none	none
Buck Island Reef National Monument, St. Croix, Virgin Islands	none	none	none	none	none	none
California Coastal National Monument, California	high	small	moderate	small	none	none
Canyons of the Ancients National Monument, Colorado	high	medium	low	small	low	none
Carrizo Plain National Monument, California	high	large	high	large	none	none
Cascade Siskiyou National Monument, Oregon	very low	very small	very low	very small	none	none
Craters of the Moon National Monument, Idaho	low	small	low	small	none	none
Giant Sequoia National Monument, California	none	none	none	none	none	none
Grand Canyon-Parashant National Monument, Arizona	very low	small	very low	small	none	none
Grand Staircase-Escalante National Monument, Utah	low	small	low	small	high	high
Hanford Reach National Monument, Washington	none	none	moderate	large	none	none
Ironwood Forest National Monument, Arizona	very low	very small	very low	very small	none	none
Kasha-Katuwe Tent Rocks National Monument, New Mexico	very low	small	very low	small	none	none
Minidoka Internment National Monument, Idaho	very low	very small	very low	very small	none	none
Pinnacles National Monument, California	very low	very small	very low	very small	none	none

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National Monuments established or expanded, 1996-2001
Oil, Gas, and Coal Appraisal Summary

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	Oil		Gas		Coal	Coalbed Gas
	Probability	Volume	Probability	Volume		
Pompey's Pillar National Monument, Montana	low	very small	low	very small	very low	very low
Santa Rosa and San Jacinto Mountains National Monument, California	none	none	none	none	none	none
Sonoran Desert National Monument, Arizona	very low	very small	very low	very small	none	none
Upper Missouri Rivers Breaks National Monument, Montana	moderate	medium	high	large	low	low
Vermillion Cliffs National Monument, Arizona	very low	small	very low	small	none	none
Virgin Islands Coral Reef National Monument, St. Johns, Virgin Islands	none	none	none	none	none	none

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Discussion of Resource Potential

Agua Fria National Monument, Arizona

Location and Description

Agua Fria National Monument, established on January 11, 2000, is located in central Arizona approximately 40 miles north of the Phoenix metropolitan area (Figure 1). The Agua Fria National Monument covers about 71,000 acres of former BLM land and includes parts of Perry Mesa, Black Mesa, and the Agua Fria River Canyon.

Published geologic maps of the area that include Agua Fria National Monument illustrate that the rocks at Agua Fria comprise a veneer of Pliocene volcanic rocks on Precambrian granites and metasedimentary rocks.

Resource Geology

The presence of volcanic, plutonic, and metasedimentary rocks prelude the presence of hydrocarbon source rocks, meaning that no petroleum system is possible in this area. No coals are present in this area.

Resource Summary

Given the rock types present in the area, there is no potential for oil, gas or coal resources within Agua Fria National Monument.

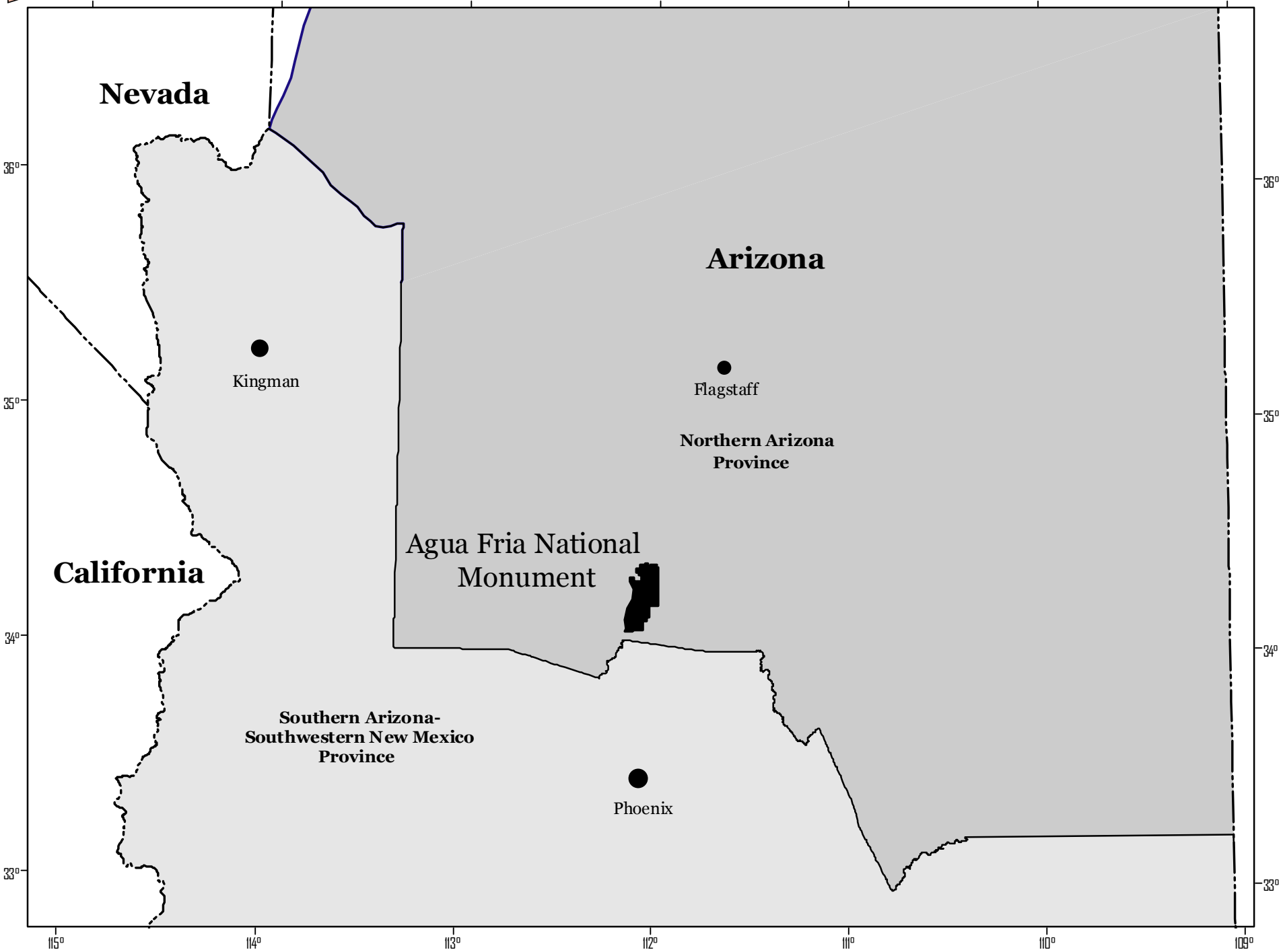

Figure 1. Map showing the location of Agua Fria National Monument, Arizona.
Agua Fria is located on the southern edge of the Colorado Plateau in the Northern Arizona Province

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Buck Island Reef National Monument, St Croix, Virgin Islands

Location and Description

Buck Island Reef National Monument is an island and coral reef about 1.5 miles north of the island of St. Croix in the U.S. Virgin Islands (Figure 2). The Monument was established in 1961 as a 880-acre area, and the Monument was significantly expanded by 18,135 acres on January 17, 2001. The boundary shown in Figure 2 was taken from a DOI website showing the approximate outline of the National Monument expansion.

St. Croix and the surrounding area are geologically complex, as this part of the Caribbean plate has a complex history of strike-slip faulting, basin development, and basin fill. St. Croix has two areas of deformed Cretaceous sedimentary rocks separated by the Tertiary Kinghill Basin, which is largely filled with Tertiary carbonate rocks. The carbonate reef of Buck Island and the surrounding area is a fringing reef that has developed on this geologic foundation.

Resource Geology

Although Cretaceous sedimentary rocks are preserved on St. Croix, no reports of potential hydrocarbon source rocks have been made in the area around St. Croix. Without a source rock, no viable petroleum system can exist in the area.

Resource Summary

Given the geology of the area of St. Croix and Buck Island Reef, there is no potential for oil, gas, or coal resources within Buck Island Reef National Monument (Table 2).

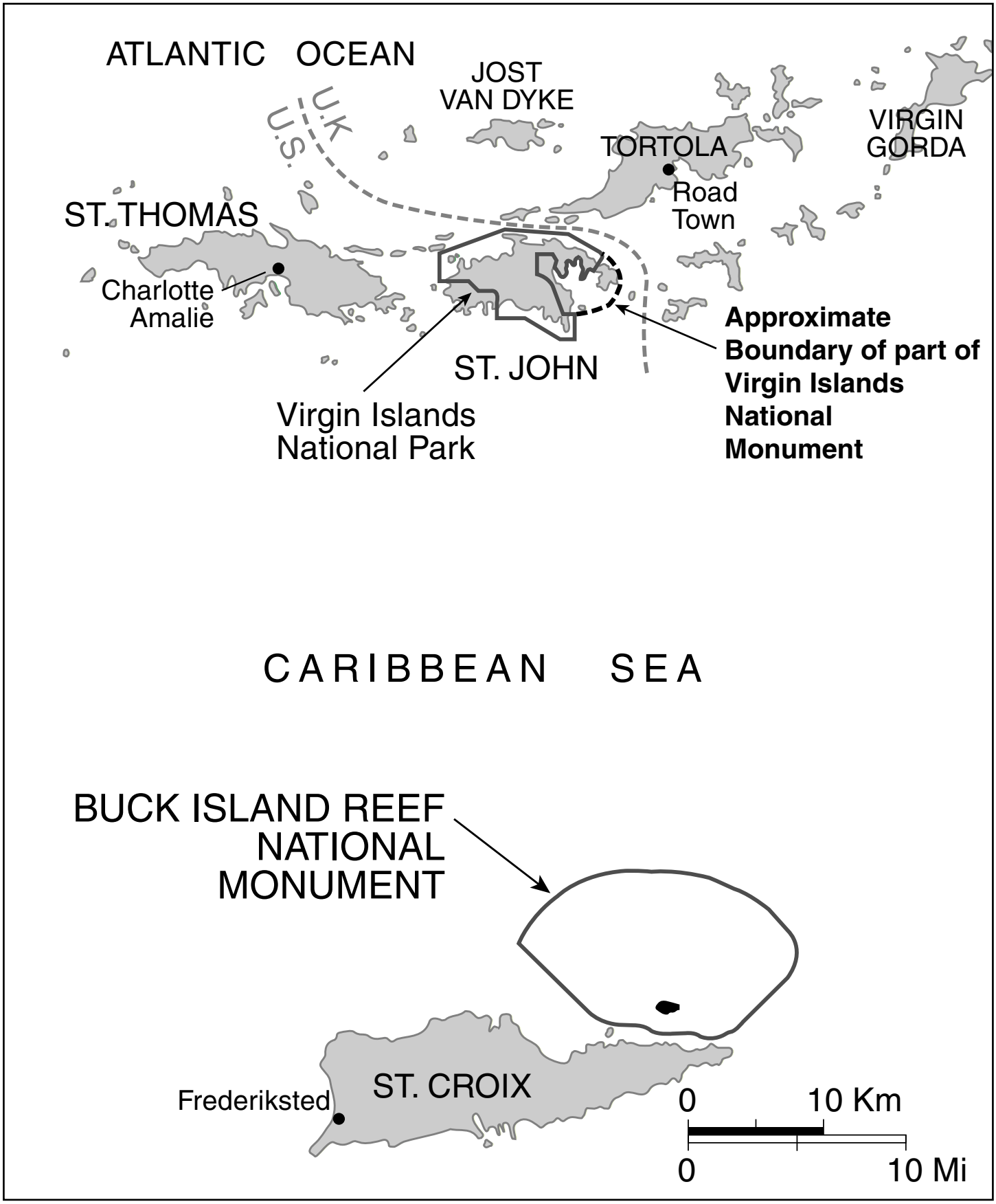

Figure 2. Map showing the location of Buck Island Reef National Monument, St. Croix, U.S. Virgin Islands. The boundary shown is the newly expanded boundary.

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California Coastal National Monument, California

Location and Description

The California Coastal National Monument, established on January 11, 2000, encompasses rocks, islands, reefs, and pinnacles that exist above the high-water mark along the entire length of the 834-mile long California coast to a distance of 12 nautical miles offshore (Figure 3). As we understood this definition, our task was to decide if oil and gas could be present beneath the limited areas described by these geologic features along the coastal zone.

Resource Geology

There are several areas along the California coast where oil and gas plays, assessed by the USGS in 1995, cross the coastline where a 1:250,000-scale map suggests offshore rocks, islands, reefs, and pinnacles; along the Santa Monica Bay-Malibu coast, the coast in the vicinity of Santa Barbara, the coast of Santa Cruz County from west of Santa Cruz to southwestern-most San Mateo County in the vicinity of Ano Neuvo Point, the coast of San Mateo County in the vicinity of Pillar Point and the town of Montara, the coast of Marin County in the area of Point Reyes National Seashore and the town of Bolinas, and Mendocino County in the vicinity of Point Arena. The discussion below focuses on the hydrocarbon plays that extend into the offshore from the Ventura Basin Province and the Central Coastal Province.

The 1995 USGS Assessment (Gautier and others, 1995) included several plays that extended into the State waters. In the Ventura Basin, the *Paleogene Offshore State Waters Play (1311)* was defined on the basis of structural traps, including anticlines and faulted anticlines, that may have been sourced by Eocene and Miocene/Pliocene organic-bearing shales, including the Rincon Shale, Monterey Formation, Modelo Formation, Sisquoc Formation, and Santa Margarita Formation. Reservoirs are predominantly marine sandstones of the Eocene and Miocene Sespe Formation.

Also in the Ventura Basin, the *Neogene Offshore State Waters Play (1312)* was defined on the basis of structural traps, including anticlines and faulted anticlines that may have been sourced predominantly by organic-

bearing mudstones of the Miocene Monterey Formation. Reservoirs are mainly Miocene to Pleistocene sandstone turbidites.

In the Central Coastal Basin, the *Point Arena Oil Play (1101)* was defined on the basis of structural traps that may have been sourced by oils from the Miocene Monterey Formation. Reservoirs are considered to be mainly Miocene-age sandstone turbidites. The *Point Reyes Oil Play (1102)* was defined on the basis of small structural traps that may have been sourced by organic-rich mudstones of the Miocene Monterey Formation, or by mudstones of the Santa Cruz Formation. Reservoirs are considered to be Neogene-age shallow marine sandstones.

Resource Summary

The probability that oil would be found in association with rocks, islands or pinnacles somewhere along the coast would be high given the plays that exist in the coastal zone, but the petroleum volumes would be very small given the limited scale of these features. For gas we concluded that the probability for occurrence would be moderate, and the potential volumes would be small.

There was no coal or coal-bed methane potential in the California Coastal National Monument.

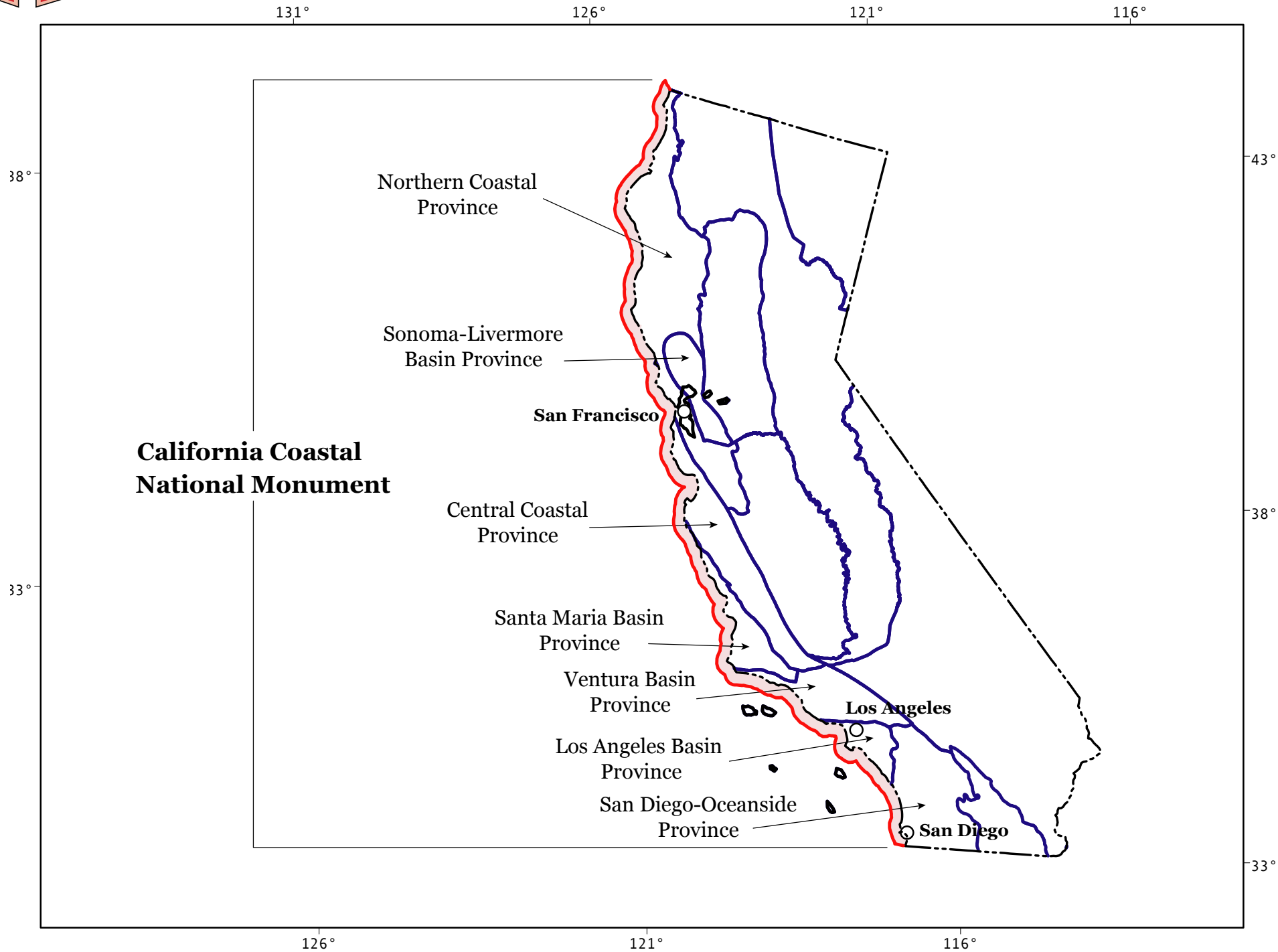

Figure 3. Map showing the location of California Coastal National Monument, California. Hydrocarbon plays that extend offshore from the Ventura Basin Province and the Central Coastal Province are described in this report.

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Canyons of the Ancients National Monument, Colorado

Location and Description

Canyons of the Ancients National Monument, established on June 9, 2000, encompasses 164,000 acres of BLM land located in the Four Corners region, about 9 miles west of Mesa Verde National Park (Figure 4).

Overall, the mesas in the area of Canyons of the Ancients National Monument are capped by the Cretaceous Dakota Sandstone, and the canyons cut through the Dakota and into underlying units such as the Morrison Formation. Canyons of the Ancients National Monument overlies the Paradox depositional basin.

Resource Geology

The USGS 1995 Assessment (Gautier and others, 1995) identified several oil and gas plays that underlie Canyons of the Ancients National Monument. The *Porous Carbonate Buildup Play (2102)* was defined on the basis of stratigraphic traps (carbonate mounds) that were sourced by organic-bearing mudstones and dolomite hydrocarbon source rocks of the Pennsylvanian-age Paradox Formation. Reservoirs are mainly phylloid algal mounds or buildups consisting of vuggy limestones and dolomites. This type of conventional reservoir may be found in the area of the National Monument.

The *Fractured Interbed Play (2103)* was defined on the basis of fracturing of the fine-grained, organic-bearing interbeds within the Pennsylvanian-age Paradox Formation. This continuous hydrocarbon accumulation may underlie the National Monument.

The *Buried Fault Blocks, Older Paleozoic Play (2101)* was defined to encompass structural traps in fault blocks that are sourced by the organic-bearing mudstones of the Pennsylvanian-age Paradox Formation. Reservoirs are considered to be Mississippian carbonates and/or Devonian sandstones.

Coals are present in the Dakota Sandstone within parts of the monument. There are as many as five individual beds at any locality as thick as 12 ft; most beds are discontinuous and are less than 3.0 thick and are

present within 200 ft of the surface. Not only are the individual coal beds discontinuous, but also the area is dissected by drainages that further restrict the areal distribution of the deposits. The shallow depth of the coal, their location on ridges, and dissection of the deposits does not allow potential for coal bed methane. The coals can be up to bituminous rank, have less than 1.0 % sulfur, but generally have high ash contents.

Resource Summary

The probability for the presence of undiscovered oil resources is high given the established oil and plays that exist in this area, and the potential volume of oil and resources is medium. For gas the probability of occurrence is estimated to be low, and the volumes estimated to be small. The potential for coal resource is considered to be low, based on the thickness and lateral continuity of the coal beds (Table 2).

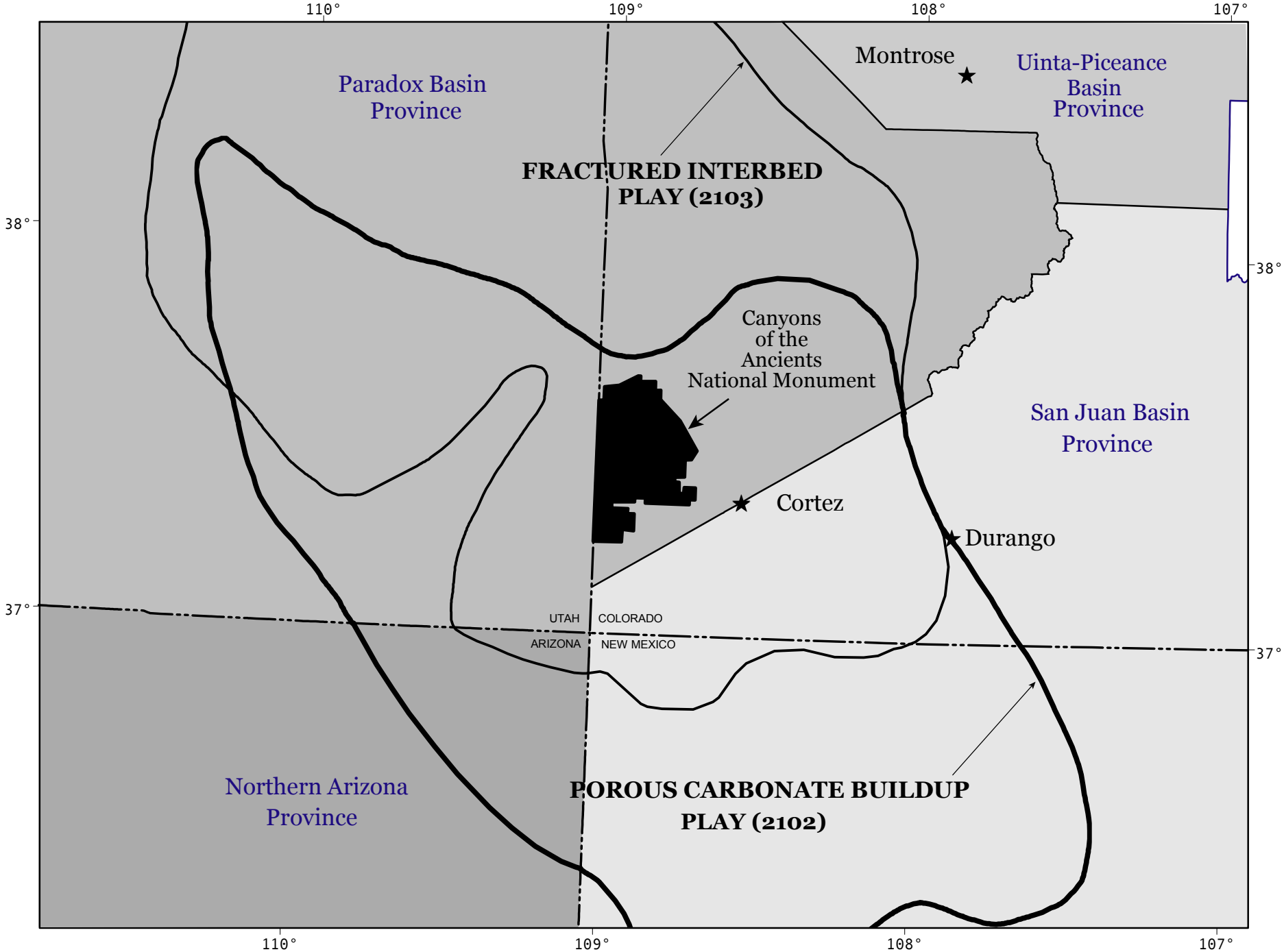

Figure 4. Map showing the location of Canyons of the Ancients National Monument, Colorado. The Monument lies within the Paradox Basin Province, and is underlain by two hydrocarbon plays.

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Carrizo Plain National Monument, California

Location and Description

The Carrizo Plain National Monument, established on January 17, 2001, is located in eastern San Luis Obispo County, California (Figure 5). The Carrizo Plain National Monument includes 204,107 acres of land adjacent to the San Andreas Fault System, which formed the Temblor Range that separates the Carrizo Plain from the San Joaquin Valley to the northeast. The boundary of the National Monument was obtained from a map posted on the BLM Bakersfield Field Office website.

The Carrizo Plain is southwest of the San Andres Fault system, which formed the Temblor Range separating the Carrizo Plain from the San Joaquin Valley. The trace of the fault system is evident in the Temblor Range, and the fault system has produced many complex geologic structures along its length, some of which underlie part of the National Monument.

The Carrizo Plain is part of the Cuyama Basin, one of the basins comprising the southern part of the Central Coastal Province (Figure 5). The San Andreas Fault System and the Temblor Range separate the Cuyama Basin and the Central Coastal Province from the San Joaquin Basin.

Resource Geology

The boundary of the Carrizo Plain National Monument suggests that the Monument covers part of the Cuyama Basin and extends slightly into the San Joaquin Basin. We examined hydrocarbon plays from both basins.

Several hydrocarbon plays were examined in the process of appraising the potential for the Carrizo Plain National Monument. The USGS 1995 Assessment (Gautier and others, 1995) defined one play in the Cuyama Basin part of the Central Coastal Province. The *Western Cuyama Basin Play (1107)* was defined on the basis of structural traps that were sourced by hydrocarbon source rocks of the Miocene Monterey Shale and/or the Soda Creek Shale, both of which remain speculative sources at present. Reservoirs are predominantly lower Miocene shallow marine sandstones. Traps are structural, related to the complex movements on the numerous faults, folds, and combination structures in this area.

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In the San Joaquin Basin, several significant oil and gas plays extend to the San Andreas Fault System, and may slightly underlie the Carrizo Plain National Monument in the area of the San Andreas Fault System. The *West Side Fold Belt sourced by post-Lower Miocene Rocks Play (1004)* contains some of the largest oil fields in the conterminous United States. The play was defined on the basis of structural traps that were sourced by Middle Miocene and younger hydrocarbon source rocks, including the Gould, Devilwater, and McDonald shales. Reservoirs are predominantly Upper Miocene and younger turbidites. Traps are largely structural, including anticlines and faulted anticlines.

The *West Side Fold Belt sourced by Pre-Middle Miocene Rocks Play (1005)* was defined on the basis of structural traps that were sourced by pre-Middle Miocene hydrocarbon source rocks (Upper Cretaceous through Lower Miocene). Reservoirs are Middle Miocene and older turbiditic sandstones. Traps are predominantly structural, as anticlines and faulted anticlines.

The *Deep Overpressured Fractured Rocks of West Side Fold and Overthrust Belt Play (1011)* was defined on the basis of structural traps that were sourced by Upper Cretaceous gas-prone shales at depth along the southwestern margin of the San Joaquin Basin. Reservoirs are postulated to be fractured shales and sandstones. This deep gas play is currently one of the most active plays in the basin; a recent deep large gas discovery has generated considerable interest in deep gas in this part of the basin.

Resource Summary

The probability for the presence of undiscovered oil and gas resources is high given the plays that underlie parts of the Monument, and the potential volume of oil and gas resources is large. There is no potential for coal and coal-bed methane (Table 2).

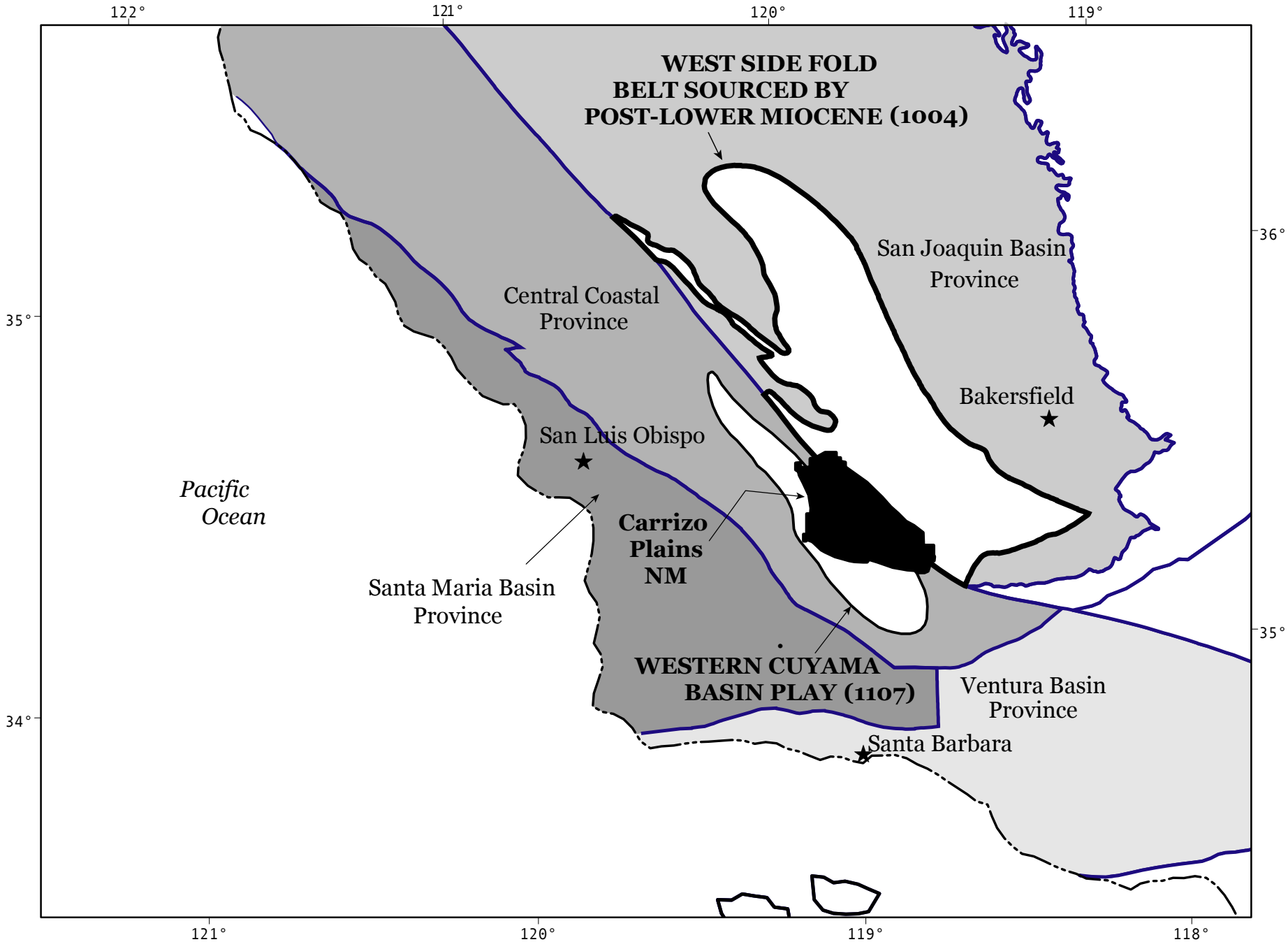

Figure 5. Map showing the location of Carrizo Plain National Monument, California. The Monument overlies part of the Cuyama Basin of the Central Coastal Province and the southwestern edge of the San Joaquin Basin.

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Cascade Siskiyou National Monument, Oregon

Location and Description

The Cascade-Siskiyou National Monument, established on June 9, 2000, encompasses about 52,000 acres of land in south-central Oregon (Figure 6). The National Monument is typified by complex geology of the Cascade Mountains, Siskiyou Mountains, and the Klamath Mountains. The boundary used in this analysis is only approximate.

Resource Geology

The 1995 USGS Assessment (Gautier and others, 1995) indicated that one speculative oil and gas play underlies the area of the National Monument. The *Hornbrook Basin-Modoc Plateau Play (1801)* was defined to include structural traps that were sourced by Cretaceous-Tertiary hydrocarbon source rocks that may occur beneath the Cascade volcanic rocks in this area. Reservoirs are postulated to be fractured Cretaceous and Tertiary sandstones. Traps are postulated to be mainly structural, related to the extensional tectonism of the basin and range province. This play is hypothetical and highly speculative at this time.

Resource Summary

The probability for the occurrence of undiscovered oil resources is very low given the speculative nature of the play, and the potential volume of oil and gas resources is very small. There is no potential for coal or coal-bed methane (Table 2).

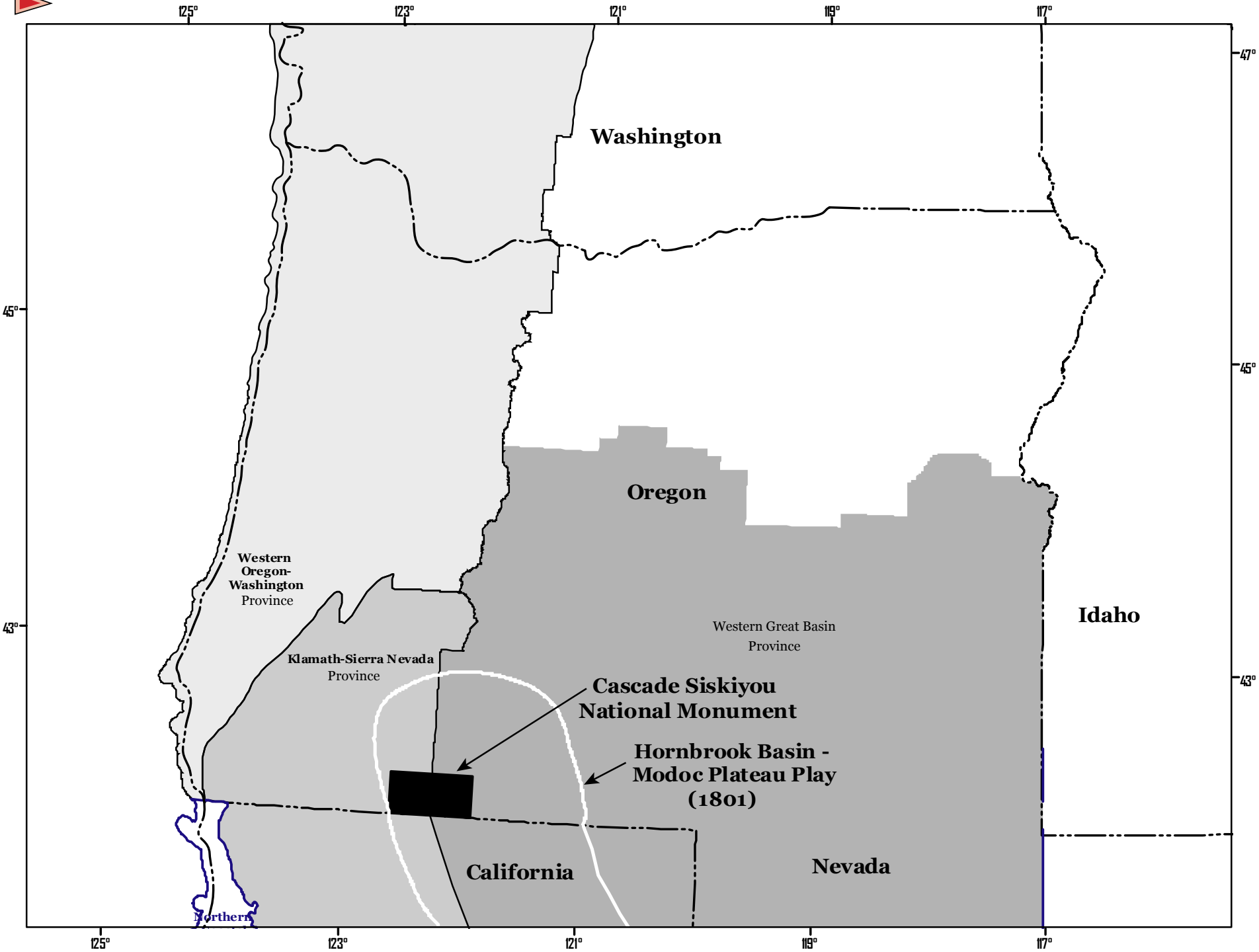

Figure 6. Map showing the location of Cascade-Siskiyou National Monument, Oregon. The Monument overlies one hypothetical hydrocarbon play.

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Craters of the Moon National Monument, Idaho

Location and Description

Craters of the Moon National Monument, established in 1924 on 54,440 acres, was expanded by 661,000 acres on November 10, 2000. The Monument is in southern Idaho along the Snake River Downwarp (Figure 7).

Resource Geology

The rocks at the surface at Craters of the Moon National Monument are regionally extensive basaltic lava flows that cover the surface of the Snake River Plain to depths of several thousand feet. The USGS 1995 Assessment (Gautier and others, 1995) defined three potential hydrocarbon plays that may underlie the volcanic rocks at Craters. The *Miocene Lacustrine (Lake Bruneau) Play (1701)* was defined on the basis of structural and stratigraphic traps that may have been sourced by Miocene age organic-rich lacustrine mudstones and shales that may be hydrocarbon source rocks. Reservoir rocks may include fluvial and marginal lacustrine sandstones and thin lacustrine carbonates. Traps are postulated to be both structural and stratigraphic.

The *Pliocene Lacustrine (Lake Idaho) Play (1702)* was defined on the basis of structural and stratigraphic traps that may have been sourced by Pliocene age organic-rich lacustrine mudstones and shales that may represent hydrocarbon source rocks. Reservoirs include fluvial and marginal lacustrine sandstones and thin lacustrine carbonates. Traps are both structural and stratigraphic.

These two plays, although not drawn to underlie the National Monument, may indeed be present under the Monument as the play boundary is quite speculative. The main question regarding the viability of the petroleum system is whether the rocks have reached temperatures sufficient for the generation of hydrocarbons. The occurrence of oil seeps and shows suggests that a petroleum system is active at some unknown scale beneath the volcanic rocks.

Resource Summary

The probability for the occurrence of undiscovered oil and gas resources is low, based upon the estimated maturity of postulated hydrocarbon source rocks, and the potential volume of oil and gas resources is small. There is no potential for coal and coal-bed methane (Table 2).

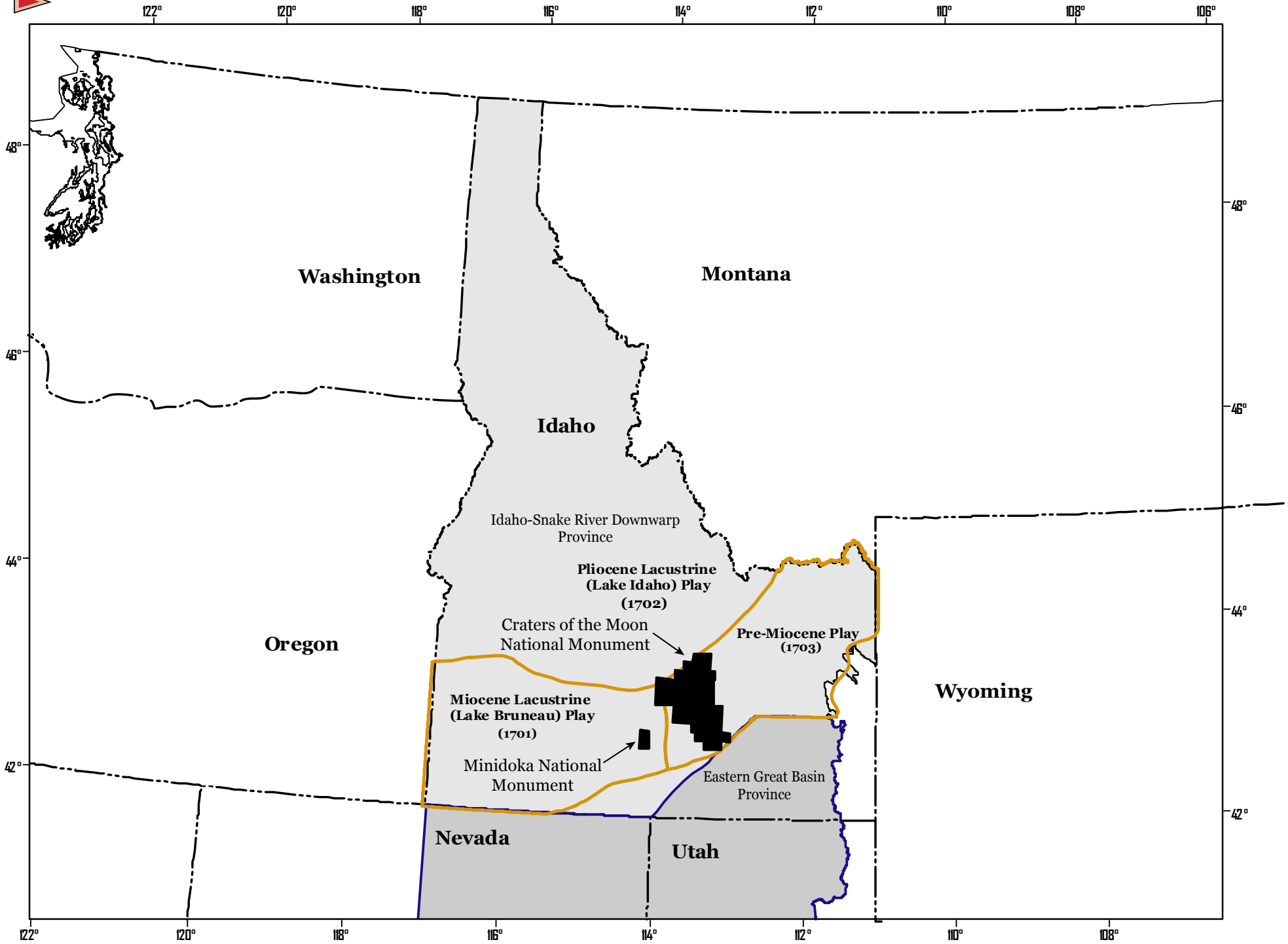

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Figure 7. Map showing the location of Craters of the Moon National Monument, Idaho, along the Snake River Plain. The Monument overlies parts of three hypothetical hydrocarbon plays.

Giant Sequoia National Monument, California

Location and Description

The Giant Sequoia National Monument, established on April 15, 2000, encompasses 328,000 acres with 34 groves of giant sequoia trees in central California (Figure 8). The Monument is in two parcels, one north and one south of the existing Sequoia National Park.

Resource Geology

Detailed geologic maps of the north and south parcels of Giant Sequoia National Monument indicate that the Monument lands are underlain by granitic rocks of Cretaceous age, part of the Sierra Nevada batholith rocks. Hydrocarbon source rocks do not occur in these rocks.

Resource Summary

Given the location of Giant Sequoia National Monument within the granitic terrain of the Sierra Nevada, we concluded that there is no potential for oil, gas, or coal resources within Giant Sequoia National Monument.

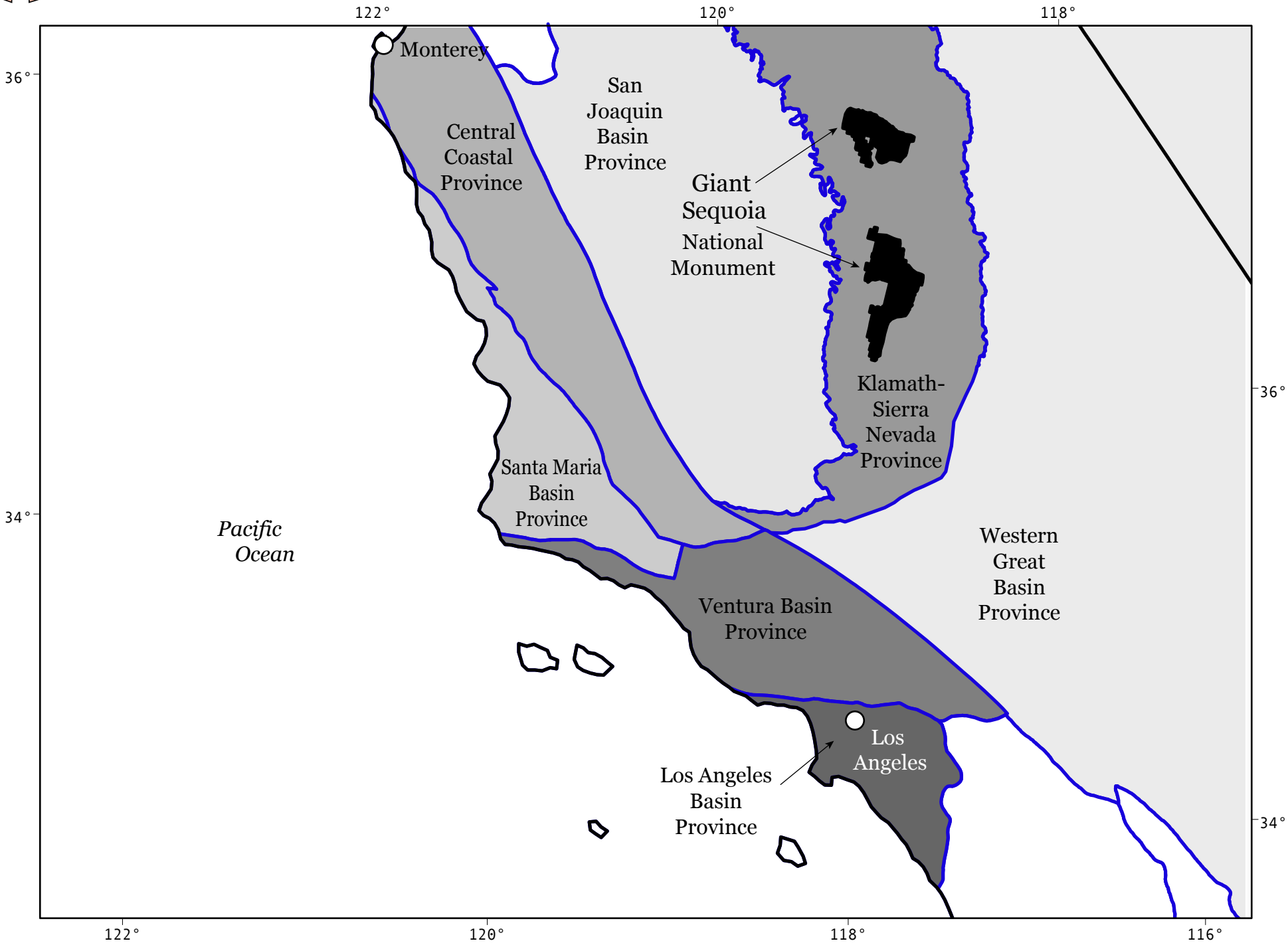

Figure 8. Map showing the location of Giant Sequoia National Monument, California. The Monument lies within the granitic terrane of the Klamath-Sierra Nevada Province.

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Grand Canyon-Parashant National Monument, Arizona

Description and Location

Grand Canyon-Parashant National Monument encompasses about 1,014,000 acres of the Colorado Plateau north of Grand Canyon National Park and east of the Nevada state line (Figure 9). Portions of Lake Mead National Recreation Area and the Shivwits Plateau are included in the National Monument.

Resource Geology

The 1995 USGS Assessment (Gautier and others, 1995) identified a hypothetical hydrocarbon play in the area of the Grand Canyon-Parashant National Monument (Figure 8). The *Hurricane Fault-Uinkaret Plateau Play (2401)* is a speculative play that postulates structural traps that may have been sourced by organic-bearing units such as the Permian Kaibab Limestone or the Hermit Shale, with reservoirs being carbonate and sandstones of the Upper Paleozoic. Several oil occurrences have been notes at the surface, providing some evidence that a petroleum system may have been active in this area. Traps are postulated to occur along the complex Hurricane Fault system. This play as mapped only occurs in the eastern part of the National Monument in the vicinity of the Hurricane Fault system.

Resource Summary

The probability for the occurrence of undiscovered oil and gas resources is very low, and the potential volume of oil and gas resources is small. There is no coal or coal-bed methane potential (Table 2).

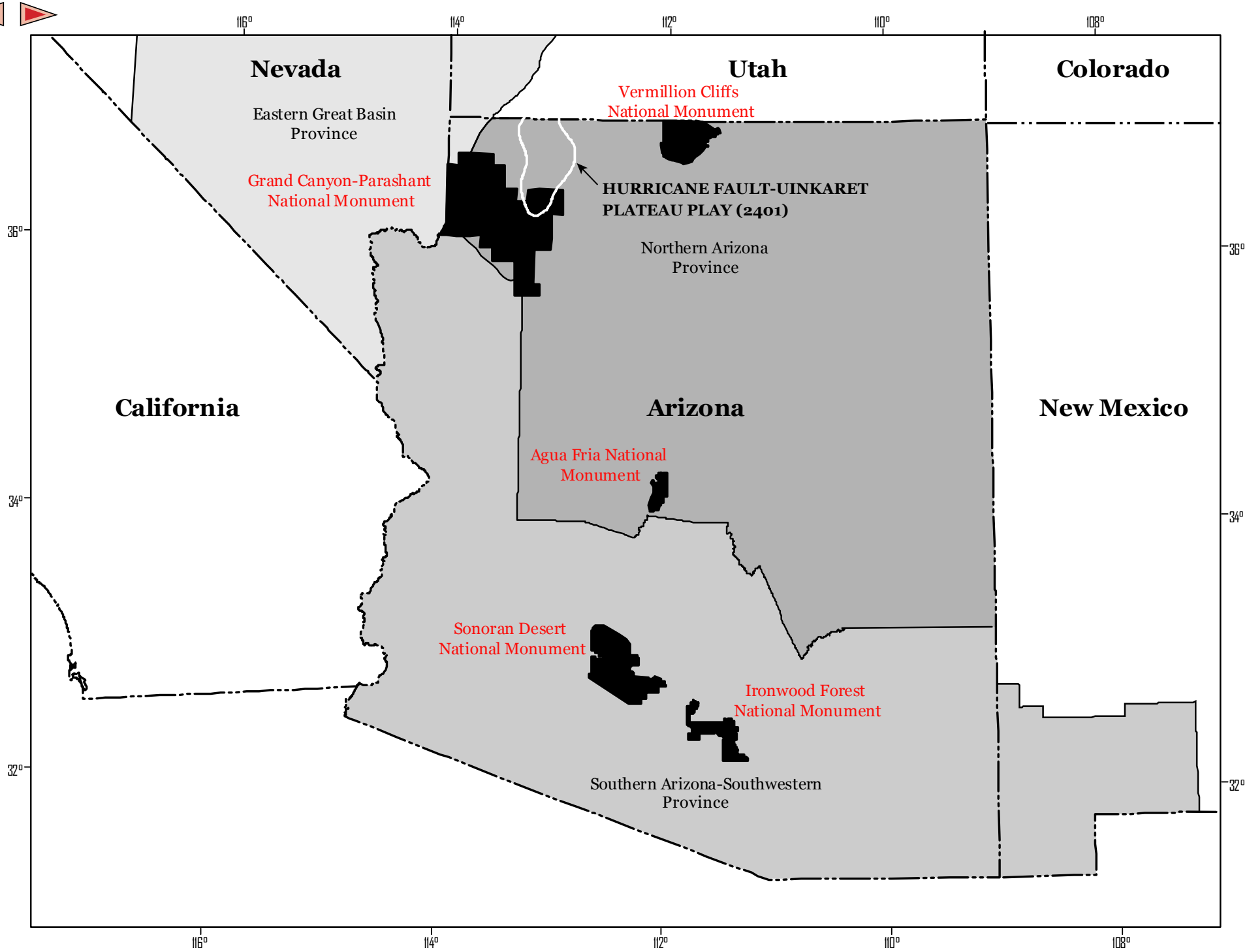

Figure 9. Map showing the location of Grand Canyon-Parashant National Monument in northwest Arizona. Part of the Monument overlies one hypothetical hydrocarbon play associated with the Hurricane Fault System.

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Grand Staircase-Escalante National Monument, Utah

Location and Description

Grand Staircase-Escalante National Monument, established on September 18, 1996, encompasses 1.9 million acres of BLM land in south-central Utah immediately north of the Arizona border (Figure 10).

This vast tract of land includes three major physiographic features; the Grand Staircase, part of the Kaiparowits Plateau, and the Escalante Canyons. The Grand Staircase consists of a series of cliffs, known as the Chocolate Cliffs, Vermilion Cliffs, White Cliffs, Gray Cliffs, and Pink Cliffs. Rocks exposed in the cliffs include the Triassic Chile Formation, Jurassic Moenave and Kayenta Formations, Jurassic Navajo Formation, Cretaceous Dakota Sandstone, Tropic Shale, Straight Cliffs Formation, Wahweap Formation, Kaiparowits Formation, and the Tertiary Claron Formation. The Kaiparowits Plateau consists of sequences of thick Cretaceous coals and shallow marine and continental sandstones exposed in numerous valleys and cliffs. The Escalante Canyons are a maze of canyons cut through Jurassic eolian sandstones.

Resource Geology

The 1995 USGS Assessment (Gautier and others, 1995) identified two hydrocarbon plays that underlie the area of Grand Staircase-Escalante National Monument. Both plays are hypothetical at present.

The *Late Proterozoic (Chuar-sourced) and Lower Paleozoic Play (2403)* is a hypothetical play defined on the basis of structural traps that may have been sourced by late Precambrian age Chuar Group source rocks. The Chuar Group is estimated to contain gray to black shales with sufficient organic richness to have potentially generated oil and gas. Reservoirs are postulated to be porous sandstones within the Chuar Group, or sandstones in the Lower Paleozoic section. Traps are expected to structural and stratigraphic. Generation and timing of hydrocarbons are unknown, but timing of migration would be critical for this play to be viable given the complex structural history of this area.

The *Permo-Triassic Unconformity Play (2106)* is defined by known accumulations of oil as tar sands, most notably the giant Tar Sand Triangle in Utah. The hydrocarbon source, however, is unknown, but several Upper Paleozoic rocks have been proposed as sources, including the Mississippian Chainman Shale, Pennsylvanian Paradox Formation, Permian Kaibab Formation, Permian Phosphoria Formation, and possibly the Precambrian Chuar Group. Reservoirs in this play included the Permian White Rim Sandstone,, DeChelley Sandstone, Coconino Sandstone, Triassic Moenkopi Formation sandstones, and Permian Kaibab Limestones. Traps are generally related to the edges of sandstones along the unconformity, as well as structural traps.

Part of the monument lies within the Kaiparowits coalfield, which contain significant deposits of coal in the John Henry Member of the Straight Cliffs Formation. Within about a 1000 ft of section there are as many as 30 individual beds and the beds are as thick as 59 ft, to a depth of 6000 ft of overburden. About 30 billion tons of coal are in areas of the Kaiparowits Plateau where geologic conditions are more favorable for current underground mining technology; only a subset of these resources are within the Monument (see reports *in* Kirschbaum and others, 2000). Based on the thick beds and high continuity of beds, there is coal bed methane potential from the Dakota Sandstone and Straight Cliffs Formation, although little is known of the thermal maturity of the coals. The John Henry coals were not assessed for coal-bed methane during the 1995 oil and gas assessment. The coals are subbituminous to bituminous in rank, and generally contain less than 1.0% sulfur.

Resource Summary

Given the size of the area, the hypothetical plays, and the lack of production to date, the probability for the presence of undiscovered oil and gas resources is low, and the potential volume of oil and gas resources is small. The probability for coal resource is high, given the thick, continuous Cretaceous coals that underlie the Monument, and there is high probability for coal-bed methane resource, although little is known of the thermal maturity of the coals (Table 2).

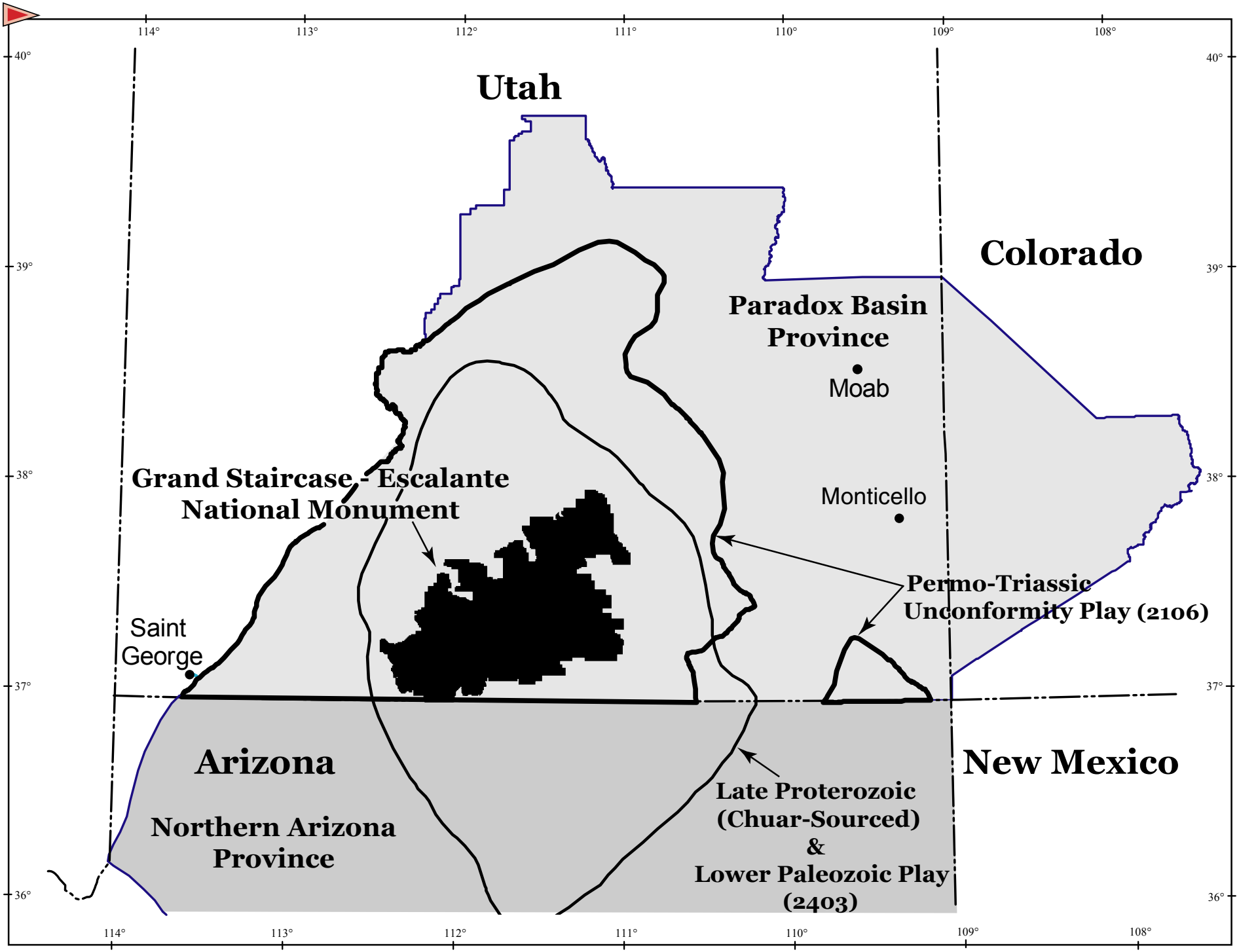

Figure 10. Map showing the location of Grand Staircase-Escalante National Monument, Utah. The Monument overlies two hypothetical hydrocarbon plays.

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Hanford Reach National Monument, Washington

Description and Location

Hanford Reach National Monument, established on June 9, 2000, encompasses 195,000 acres of former DOE land around a 51-mile reach of the Columbia River in south-central Washington (Figure 11). The reach begins at the foot of the Priest Rapids Dam and extends 51 miles to the McNary Dam, just north of the town of Richland, Washington. The Monument lands were formerly part of the DOE Hanford Nuclear Reservation.

The area around Hanford Reach National Monument is characterized by basaltic volcanic lava flows that have reached thicknesses of several thousand feet. The plays described below are beneath this pile of volcanic rocks. As a consequence of the thick volcanic rocks, few wells have been drilled in these plays.

Resource Geology

The 1995 USGS Assessment (Gautier and others, 1995) identified two hydrocarbon plays that underlie the area of Hanford Reach National Monument.

The *Northwestern Columbia Plateau Gas Play (0501)* is a conventional gas play (Figure 10) defined by structural traps that may have been sourced by lacustrine and fluvial organic bearing shales of the Swauk and Chumstick formations and coals of the Roslyn Formation. Reservoirs are mainly Eocene and Oligocene fluvial sandstones. Traps are mainly structural, as Miocene and younger anticlines and thrust-related folds. The few wells drilled into this play have had significant gas flows, indicating that a viable petroleum system exists in this area.

The *Columbia Basin- Basin Centered Gas Play (0503)* was defined to encompass a potential continuous (basin-centered) gas accumulation in the Columbia Basin (Figure 11). Source rocks are postulated to be interbedded coals and carbonaceous shales of Eocene age. Reservoirs are considered to be mainly fluvial sandstones of Eocene age, but with the definition of continuous gas, all lithologies are considered to be potential reservoirs. The

thermal maturity of the shales demonstrated that sufficient levels of maturation have been reached for the generation of gas in this play. Significant quantities of gas were assessed in this play.

The several thousand feet of volcanic cover essentially eliminates any coal and coal-bed methane as a resource.

Resource Summary

The probability for the presence of undiscovered gas resources is moderate, but the potential volume of gas resource is large. However, the gas resources are considered to be continuous rather than conventional, and the potential for the continuous gas resources may be longer term rather than shorter term. There is no potential for coal or coal-bed methane (Table 2).

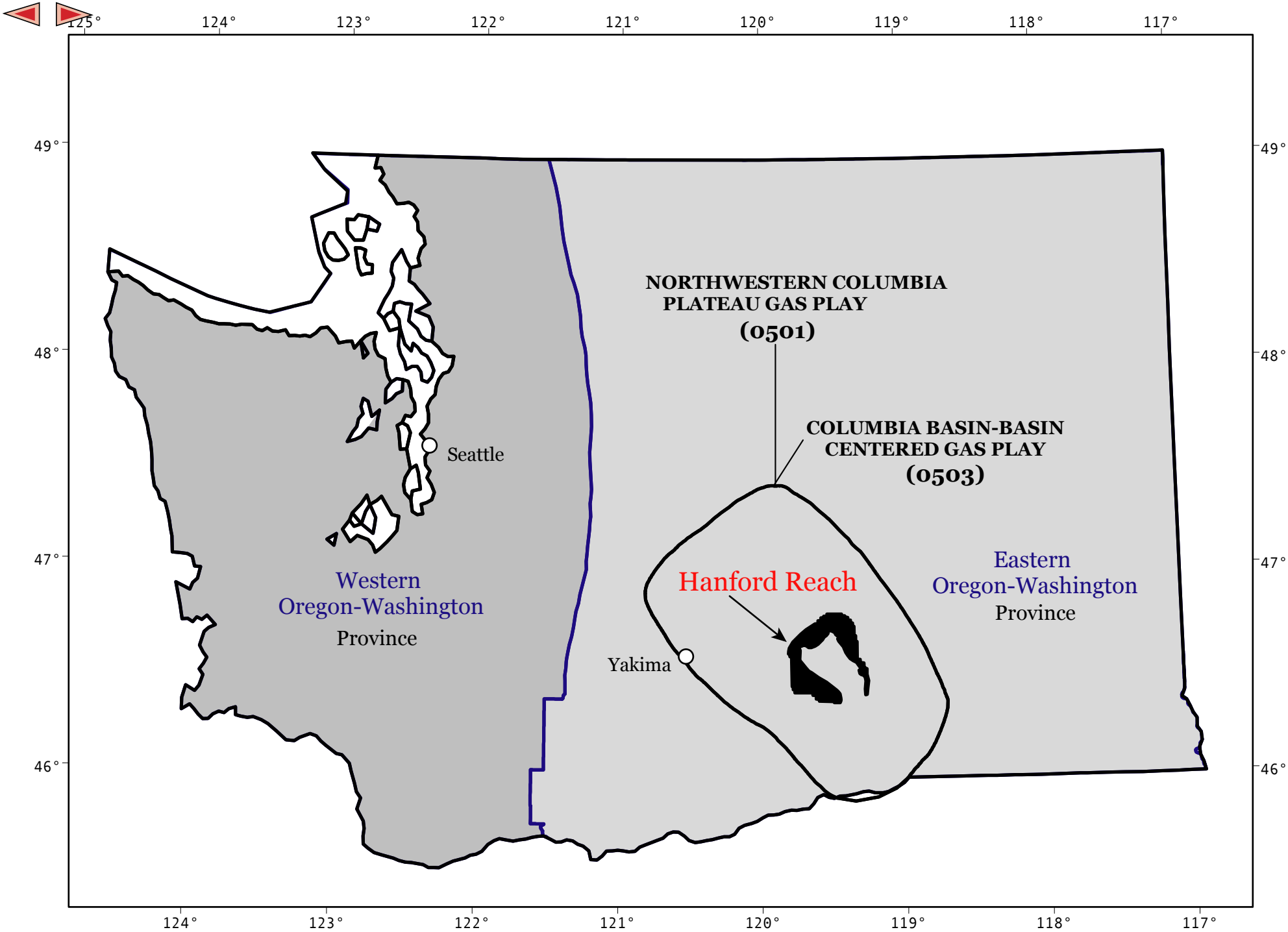

Figure 11. Map showing the location of Hanford Reach National Monument, Washington. The Monument overlies two hypothetical gas plays.

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Ironwood Forest National Monument, Arizona

Description and Location

The Ironwood Forest National Monument, established on June 9, 2000, encompasses about 129,000 acres of land located about 25 miles northwest of Tucson, Arizona (Figure 12). The National Monument contains stands of ironwood trees that can live for more than 800 years.

Ironwood Forest National Monument falls within the Basin and range structural province that wraps around the southwestern part of the Colorado Plateau. The basin and range province is characterized by extensional structures leading to narrow basins separated by elongate mountain ranges, the basins commonly filled with several thousand feet of Tertiary continental rocks.

Resource Geology

The 1995 USGS Assessment (Gautier and others, 1995) did not identify any hydrocarbon plays in the area of Ironwood Forest National Monument. However, plays in others areas with basin and range geology suggest play types that may underlie Ironwood Forest. The *Pedregosa Basin Play (2502)*, defined to the east of Ironwood Forest National Monument, was defined on the basis of structural traps that may have been sourced by Upper Paleozoic hydrocarbon source rocks (Mississippian, Pennsylvanian, Permian) with Paleozoic sandstone and carbonate reservoirs. Traps may be related to the extensional structures common to the basins and range, tilted blocks, and drag folds on faults. Such a geologic play concept may apply to the area underlying Ironwood Forest National Monument, although this relationship is quite speculative at present.

Resource Summary

The probability for the occurrence of undiscovered oil and gas resources is very low, and the potential volume of oil and gas resources is very small. There is no potential for coal or coal-bed methane (Table 2).

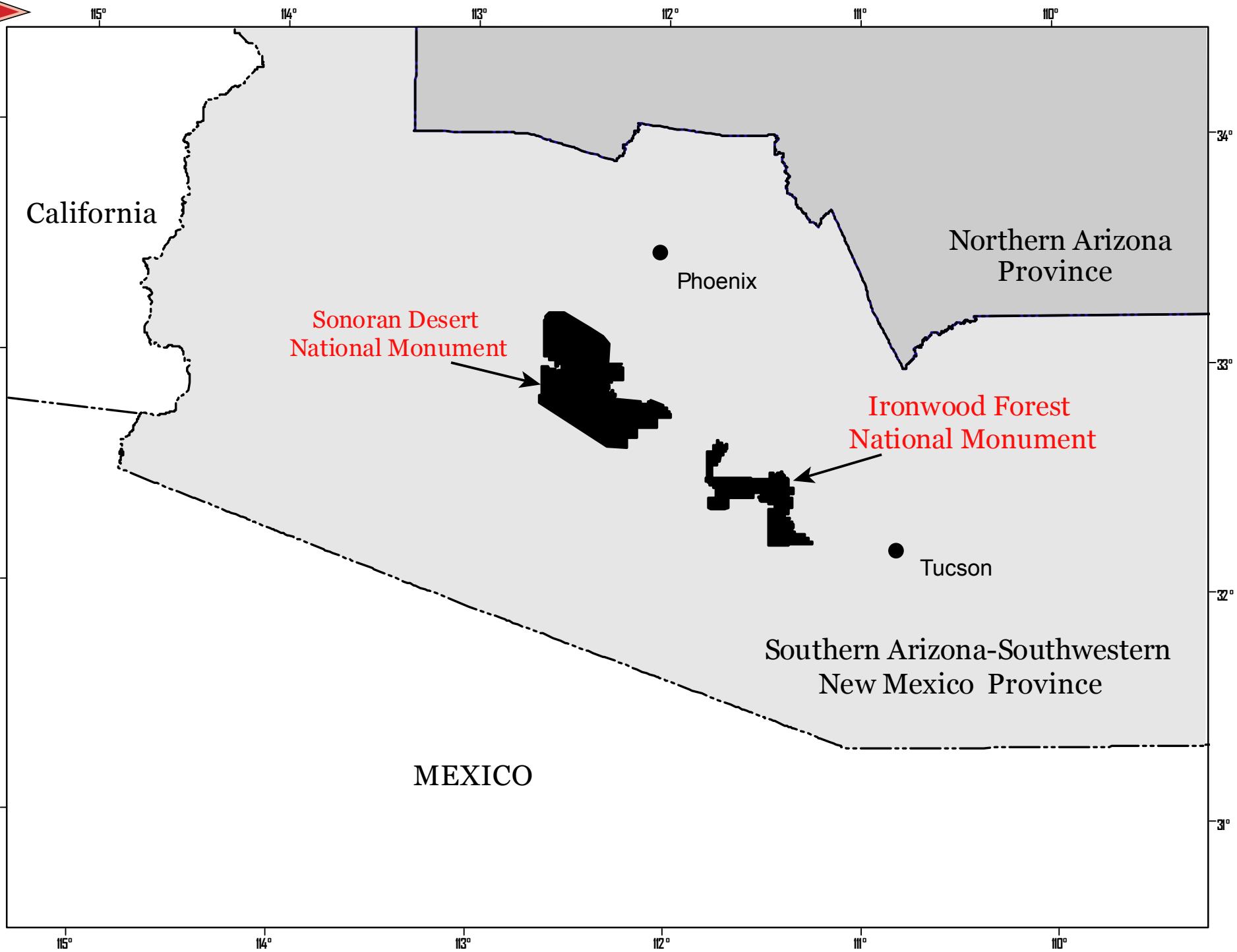

Figure 12. Map showing the location of Ironwood Forest National Monument, Arizona.

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Kasha-Katuwe Tent Rocks National Monument, New Mexico

Location and Description

Kasha-Katuwe Tent Rocks National Monument, established on January 17, 2001, is located in north-central New Mexico near the town of Los Alamos, New Mexico (Figure 13). The National Monument, encompassing approximately 4100 acres of former BLM land, includes large, tent-shaped rocks along the bluffs of Peralta Canyon.

Resource Geology

Rocks at the surface in the area of Kasha-Katuwe Tent Rocks National Monument are mainly Tertiary and Quaternary volcanic rocks, but beneath the volcanic rocks may be Pennsylvanian through Tertiary sedimentary rocks along the northwestern margin of the Albuquerque Basin. Hydrocarbon source rocks may be in the Pennsylvanian, Jurassic, and Tertiary parts of the sedimentary section. Given the high heat flow in this rift basin, some of the source rocks may have reached sufficient temperatures for hydrocarbon generation, expulsion, and migration. Potential hydrocarbon reservoirs included Permian, Jurassic, and Upper Cretaceous sandstones.

The 1995 USGS Assessment (Gautier and others, 1995) defined one hydrocarbon play in the vicinity of Kasha-Katuwe. The *Albuquerque Basin Play (2301)* was defined on the basin of potential structural traps sourced by possible source rocks of the Cretaceous Greenhorn interval, and possibly the Niobrara Formation equivalent of the middle part of the Mancos Shale. Reservoirs were considered to be Cretaceous-age coastal and marine sandstones. This play is hypothetical at present.

Resource Summary

Given the location of Kasha-Katuwe Tent Rocks National Monument along the margin of the Albuquerque Basin, and the possibility for hydrocarbon source rocks and reservoirs, we concluded that there is a very low probability for the occurrence of oil and gas, and the potential volumes are estimated to be small. There is no potential for coal or coal-bed methane (Table 2).

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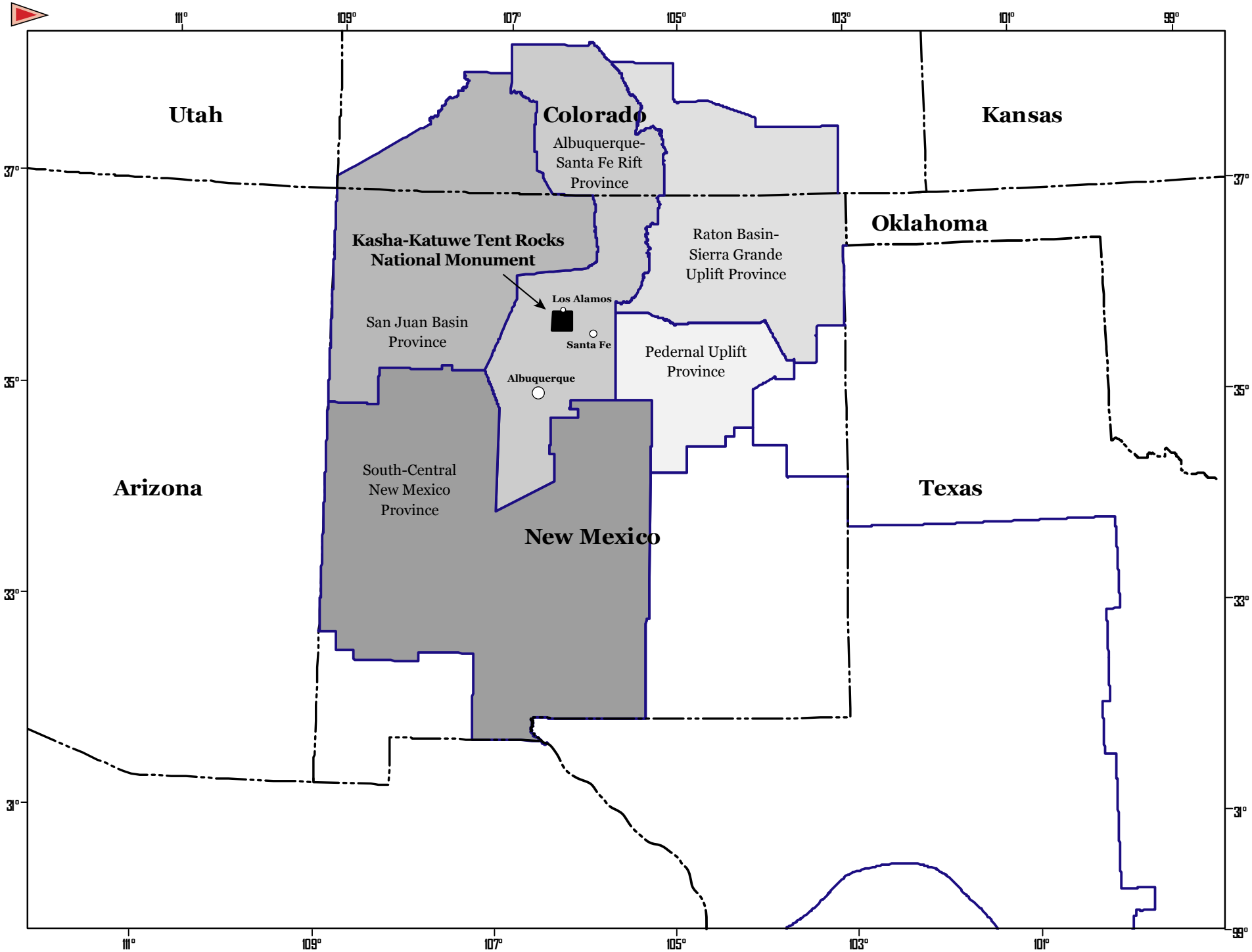

Figure 13. Map showing the location of Kasha-Katuwe Tent Rocks National Monument, New Mexico. The Monument is located near the margin of the Albuquerque Basin.

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Minidoka Internment National Monument, Idaho

Location and Description

Minidoka Internment National Monument, established on January 17, 2001, is a 73-acre parcel of land about 20 miles northeast of Twin Falls, Idaho. The National Monument includes portions of the Minidoka Relocation Center, a World War II era Japanese-American internment camp (Figure 14).

Resource Geology

The rocks at the surface at Mindoka Internment National Monument are regionally extensive basaltic lava flows that cover the surface of the Snake River Plain to depths of several thousand feet. The 1995 USGS Assessment (Gautier and others, 1995) defined three potential hydrocarbon plays that may underlie the volcanics at Mindoka. The *Miocene Lacustrine (Lake Bruneau) Play (1701)* was defined on the basis of structural and stratigraphic traps that may have been sourced by Miocene age organic-rich lacustrine mudstones and shales (possible hydrocarbon source rocks). Reservoir rocks may include fluvial and marginal lacustrine sandstones and thin lacustrine carbonates. Traps are postulated to be both structural and stratigraphic in origin.

The *Pliocene Lacustrine (Lake Idaho) Play (1702)* was defined on the basis of structural and stratigraphic traps that may have been sourced by Pliocene age organic-rich lacustrine mudstones and shales (possible hydrocarbon source rocks). Reservoirs include fluvial and marginal lacustrine sandstones and thin lacustrine carbonates. Traps are both structural and stratigraphic.

The main question is whether the rocks have reached temperatures sufficient for the generation of hydrocarbons. The occurrence of oil seeps and shows suggests that a petroleum system is active at some unknown scale beneath the volcanic rocks of the Snake River Plain.

Resource Summary

The probability for the presence of undiscovered oil and gas resources is very low, depending upon the maturity of postulated hydrocarbon source rocks, and the potential volume of oil and gas resources is very small. There is no potential for coal and for coal-bed methane (Table 2).

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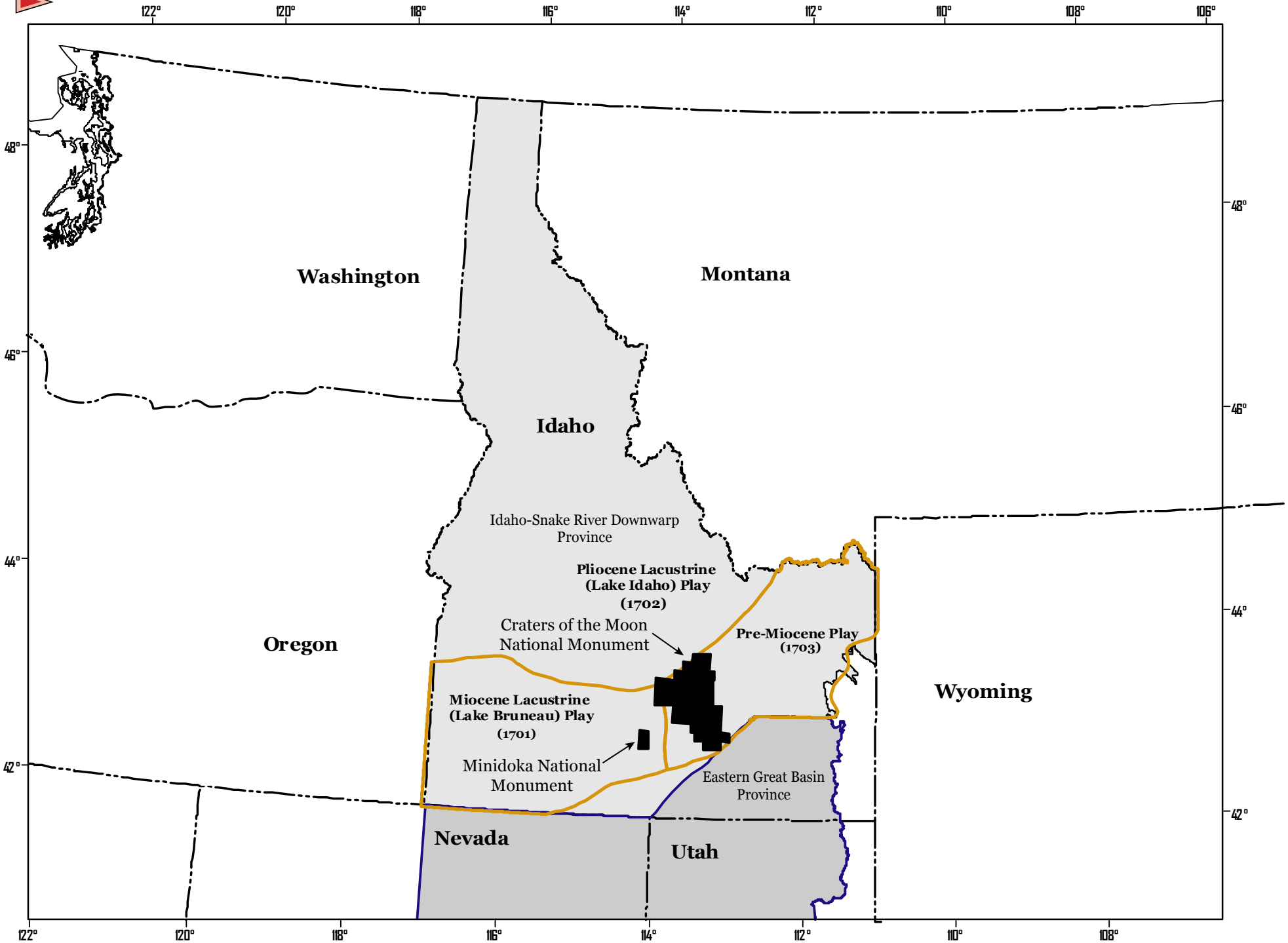

Figure 14. Map showing the location of Minidoka Internment National Monument, Idaho. The Monument overlies two hypothetical hydrocarbon plays.

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Pinnacles National Monument, California

Location and Description

Pinnacles National Monument, designated a National Monument in 1908, was expanded on January 22, 2000, adding approximately 7,960 acres to the existing 16,265 acres of the Monument. Pinnacles National Monument is located about 65 miles southeast of San Jose, California in the Gabilan Mountains, east of central California's Salinas Valley (Figure 15).

Pinnacles National Monument contains spires, cliffs, and canyons eroded into volcanic rocks of the Gabilan Mountains. The original National Monument was situated entirely within thin Miocene volcanic rocks that overlie granites and metamorphic rocks of the Salinia terrane, but some of the area included in the expansion of 2000 lies to the southeast of the original Monument where sedimentary rocks may exist in the subsurface.

Resource Geology

The 1995 USGS Assessment (Gautier and others, 1995) defined the *Bitterwater Oil Play (1105)* in the Bitterwater Valley immediately east of the Gabilan Mountains. The hydrocarbon source rock for this play is unknown, but a Miocene source was suggested for the oils at Bitterwater Field and for oil shows in several wells in the area. Traps are dominantly anticlines and faulted anticlines. The potential for undiscovered resources in this play decreases to the north towards the area where Pinnnacles was expanded, but the potential remains for hydrocarbons beneath the southeasternmost part of Pinnacles National Monument.

Resource Summary

Given that only a small part of the acreage that was added to Pinnacles has hydrocarbon potential, the probability for the presence of undiscovered oil and gas resources is very low, and the potential volume of oil and gas resources is very small. There is no coal or coal-bed methane potential (Table 2).

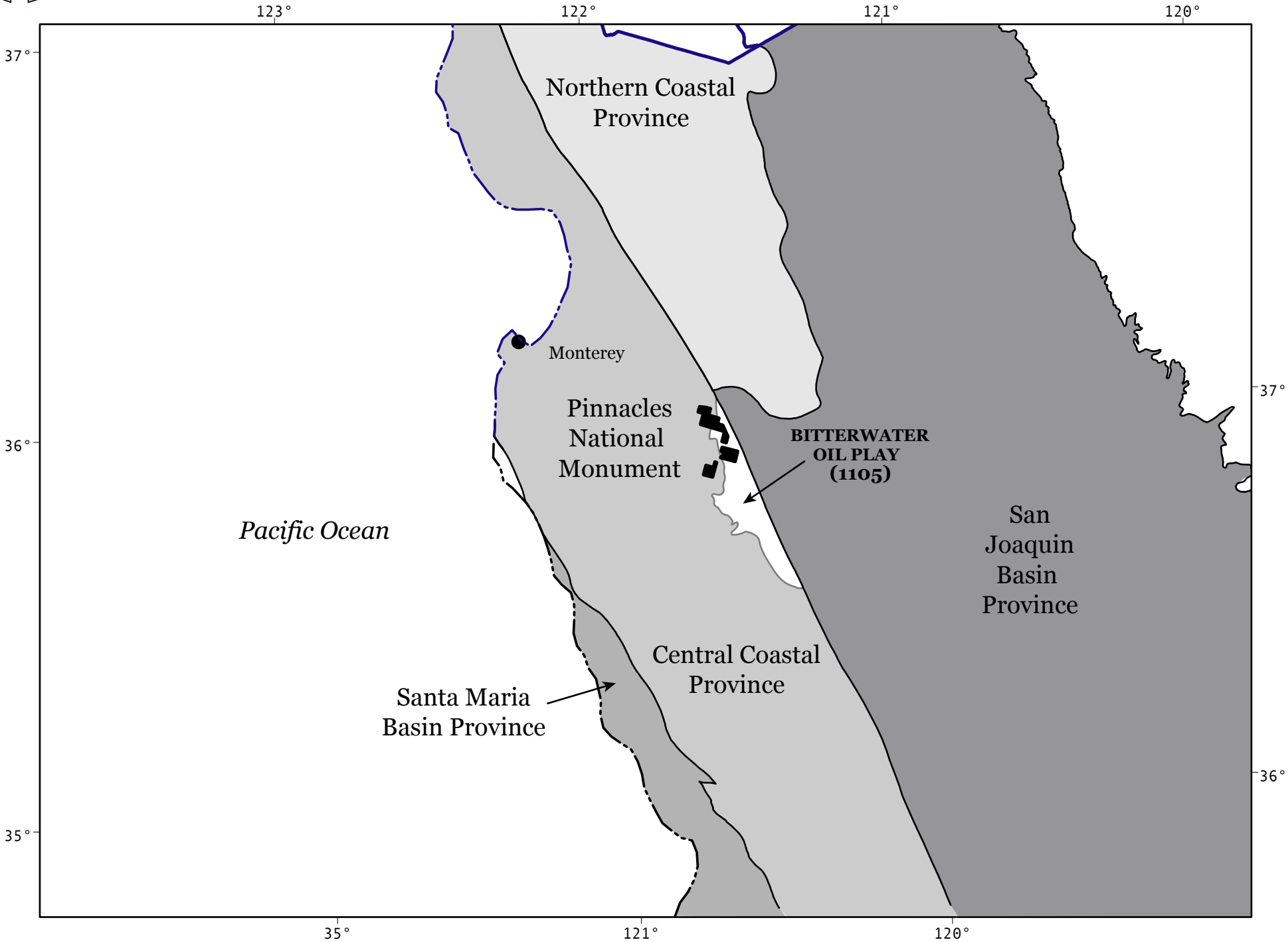

Figure 15. Map showing the location of Pinnacles National Monument, California. The eastern part of the Monument overlies part of the Bitterwater Oil Play.

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Pompey's Pillar National Monument, Montana

Location and Description

Pompey's Pillar National Monument, established on January 17, 2001, is located along the Yellowstone River about 28 miles east of Billings, Montana (Figure 16). Pompey's Pillar encompasses about 51 acres of sandstone cliffs that provided a natural landmark for hundreds of generations of Native Americans and many explorers, including Lewis and Clark.

Resource Geology

The 1995 USGS Assessment (Gautier and others, 1995) defined several established oil and gas plays in central Montana. For this discussion we selected two plays that highlight the diversity of plays and hydrocarbon occurrence in central Montana as a guide for what may be expected beneath the National Monument.

The *Devonian-Mississippian Carbonates Play (2805)* was defined on the basis of stratigraphic traps that may have been sourced by organic-rich mudstones of the Bakken Shale, Three Forks Formation, Lodgepole Formation, and Heath Formation as hydrocarbon source rocks. Reservoirs are porous dolomites of the Nisku Formation, and bioclastic mounds of the Mississippian Madison Formation. Traps in this play are largely stratigraphic, and are related to depositional facies within the carbonate deposits. Several stacked plays of this type were defined in the Central Montana Province.

The *Shallow Cretaceous Biogenic Gas Play (2809)* is a continuous gas accumulation defined to include gas resources that are formed in shallow sandstones reservoirs by the biogenic breakdown of organic matter in interbedded shales by anaerobic bacteria. Typical reservoirs are the Cretaceous Eagle Sandstone, a shallow marine sandstone.

Resource Summary

Given the area of the National Monument (51 acres), we concluded that the probability for the presence of undiscovered oil and gas resources is low, and the potential volume of oil and gas resources is very small. There

is very low potential for coal and for coal-bed methane (Table 2). However, given the size of the National Monument, this appraisal may be too high.

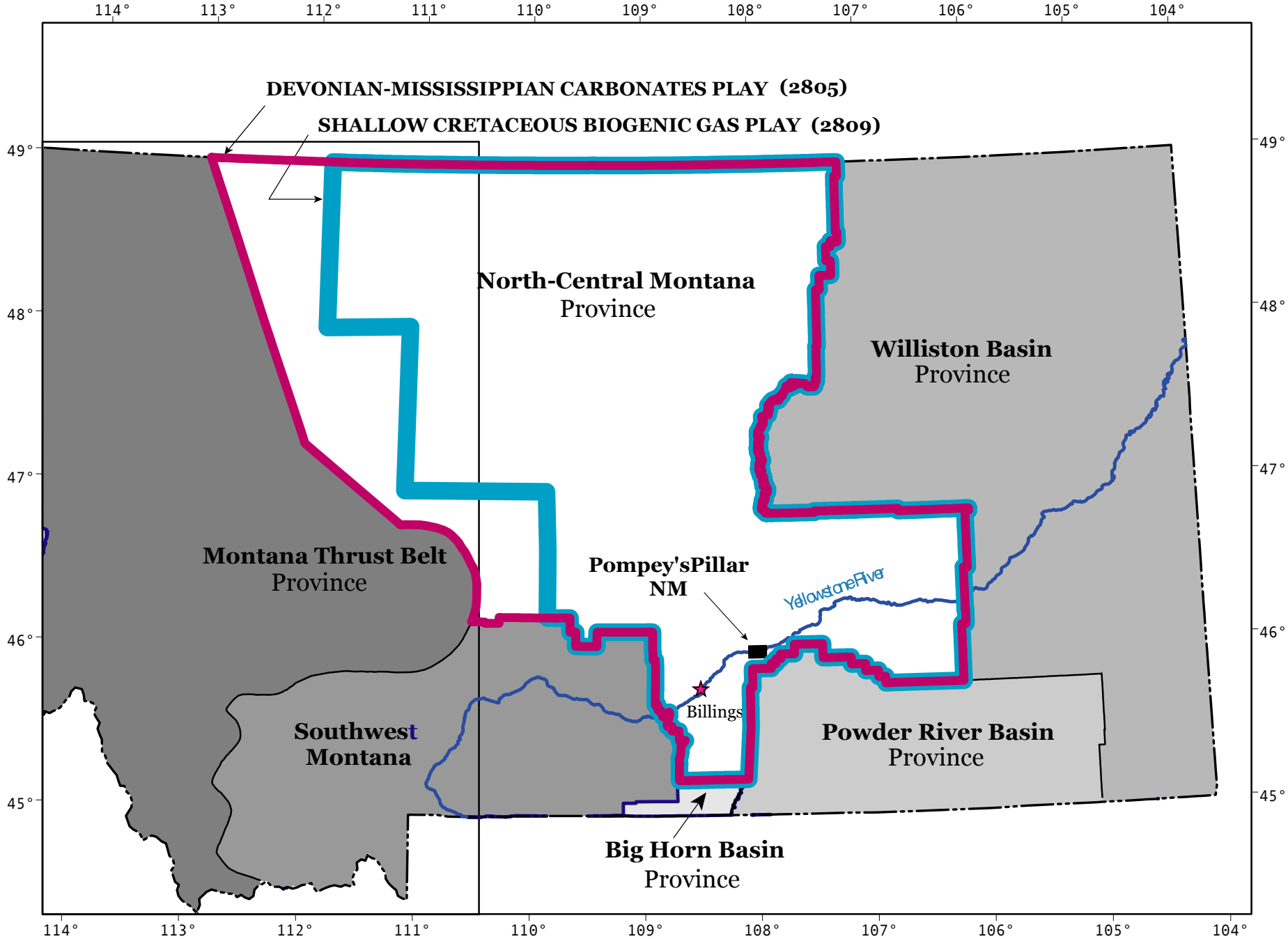

Figure 16. Map showing the location of Pompey's Pillar National Monument, Montana. The Monument overlies several oil and gas plays.

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Santa Rosa and San Jacinto Mountains National Monument, California

Location and Description

Santa Rosa and San Jacinto Mountains National Monument, established on October 25, 2000, is a 281,600-acre tract of land in the southern California desert immediately west of Palm Springs (Figure 17).

Resource Geology

Published geologic maps of the area including the National Monument demonstrate that the area is largely underlain by granites of Cretaceous age.

Resource Summary

Given the location of Santa Rosa and San Jacinto Mountains National Monument within the granitic rocks of Cretaceous age, there is no potential for oil, gas, or coal resources within Santa Rosa and San Jacinto Mountains National Monument (Table 2).

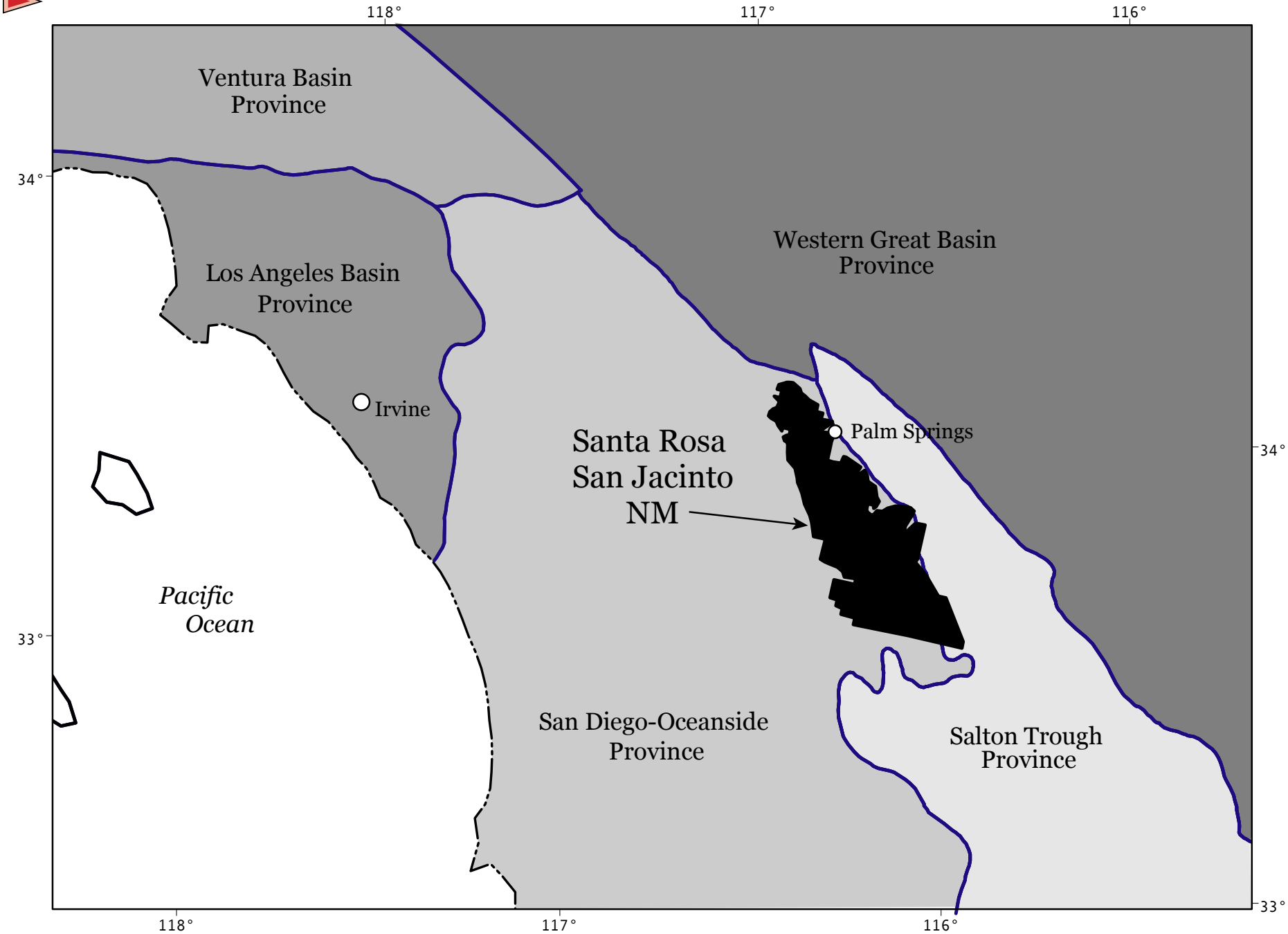

Figure 17. Map showing the location of Santa Rosa and San Jacinto Mountains National Monument, California.

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Sonoran Desert National Monument, Arizona

Location and Description

The Sonoran Desert National Monument, established on January 17, 2001, is located in south-central Arizona, about 60 miles south of Phoenix (Figure 18).

Resource Geology

The Sonoran Desert National Monument lies within the basin and range province, an area of complex geology. The 1995 USGS Assessment (Gautier and others, 1995) did not identify any hydrocarbon plays in the area of Sonoran Desert National Monument. However, plays in others areas with basin and range geology suggest play types that may underlie Sonoran Desert National Monument. The *Pedregosa Basin Play (2502)*, defined to the east of Sonoran Desert National Monument, is defined on the concept of structural traps that may have been sourced by Upper Paleozoic hydrocarbon source rocks (Mississippian, Pennsylvanian, Permian) with Paleozoic sandstone and carbonate reservoirs. Traps may be related to the extensional structures common to the basins and range, tilted blocks, and drag folds on faults. Such a geologic play concept may apply to the area underlying Sonoran Desert National Monument, although this relationship is quite speculative at present.

Resource Summary

We concluded that the probability for the presence of undiscovered oil and gas resources is very low, and the potential volume of oil and gas resources is very small. For coal, we concluded that there is no potential for coal and for coal-bed methane (Table 2).

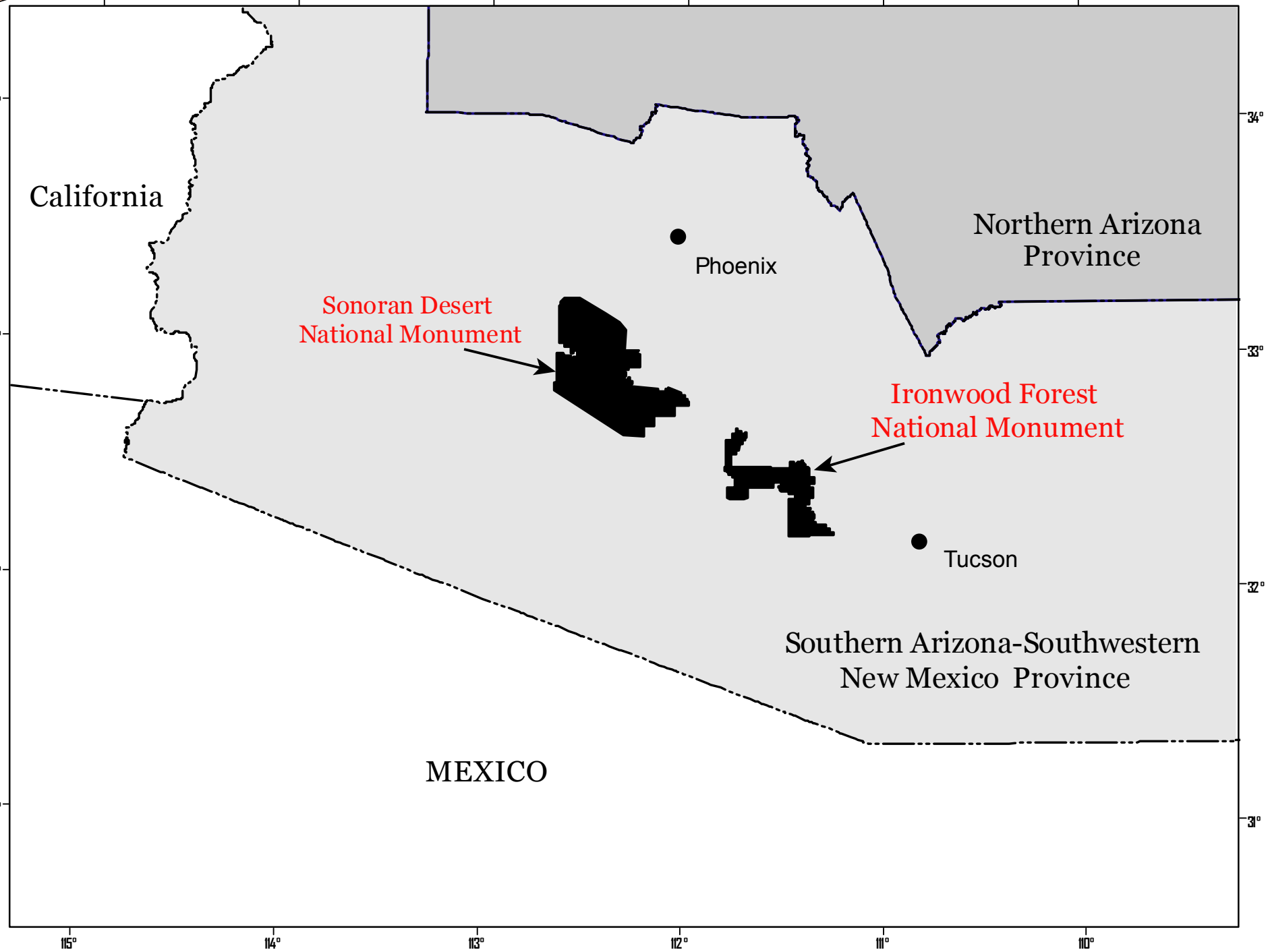

Figure 18. Map showing the location of Sonoran Desert National Monument, Arizona. The Monument is situated on granites of the San Diego-Oceanside Province.

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Upper Missouri River Breaks National Monument, Montana

Location and Description

The Upper Missouri River Breaks National Monument, established on January 17, 2002, encompasses 337,346 acres of Federal land along a 149-mile stretch of the Upper Missouri National Wild and Scenic River through north-central Montana (Figure 19). In addition to 149 miles of the Upper Missouri River, the Monument includes the adjacent Breaks country, portions of Arrow Creek, Antelope Creek, and the Judith River.

Resource Geology

The 1995 USGS Assessment (Gautier and others, 1995) defined several established oil and gas plays in central Montana. For this discussion we selected two plays that highlight the diversity of plays and hydrocarbon occurrence in central Montana as a guide for what may be expected beneath the National Monument.

The *Devonian-Mississippian Carbonates Play (2805)* was defined on the basis of stratigraphic traps that may have been sourced by organic-rich mudstones of the Bakken Shale, Three Forks Formation, Lodgepole Formation, and Heath Formation as hydrocarbon source rocks. Reservoirs are porous dolomites of the Nisku Formation, and bioclastic mounds of the Mississippian Madison Formation. Traps in this play are largely stratigraphic, and are related to depositional facies within the carbonate deposits. Several stacked plays of this type were defined in the Central Montana Province.

The *Shallow Cretaceous Biogenic Gas Play (2809)* was a continuous gas accumulation defined to include gas resources that are formed in shallow sandstones reservoirs by the biogenic breakdown of organic matter in shales by anaerobic bacteria. Typical reservoirs are the Cretaceous Eagle Sandstone, a shallow marine sandstone.

Resource Summary

The probability for the presence of undiscovered oil resources is moderate, and the potential volume of oil resources is medium; the

probability for the presence of gas resources is high, and the potential volume of gas is estimated to be large. Although there is much uncertainty regarding coal, we concluded that there is low potential for coal and coal-bed methane (Table 2).

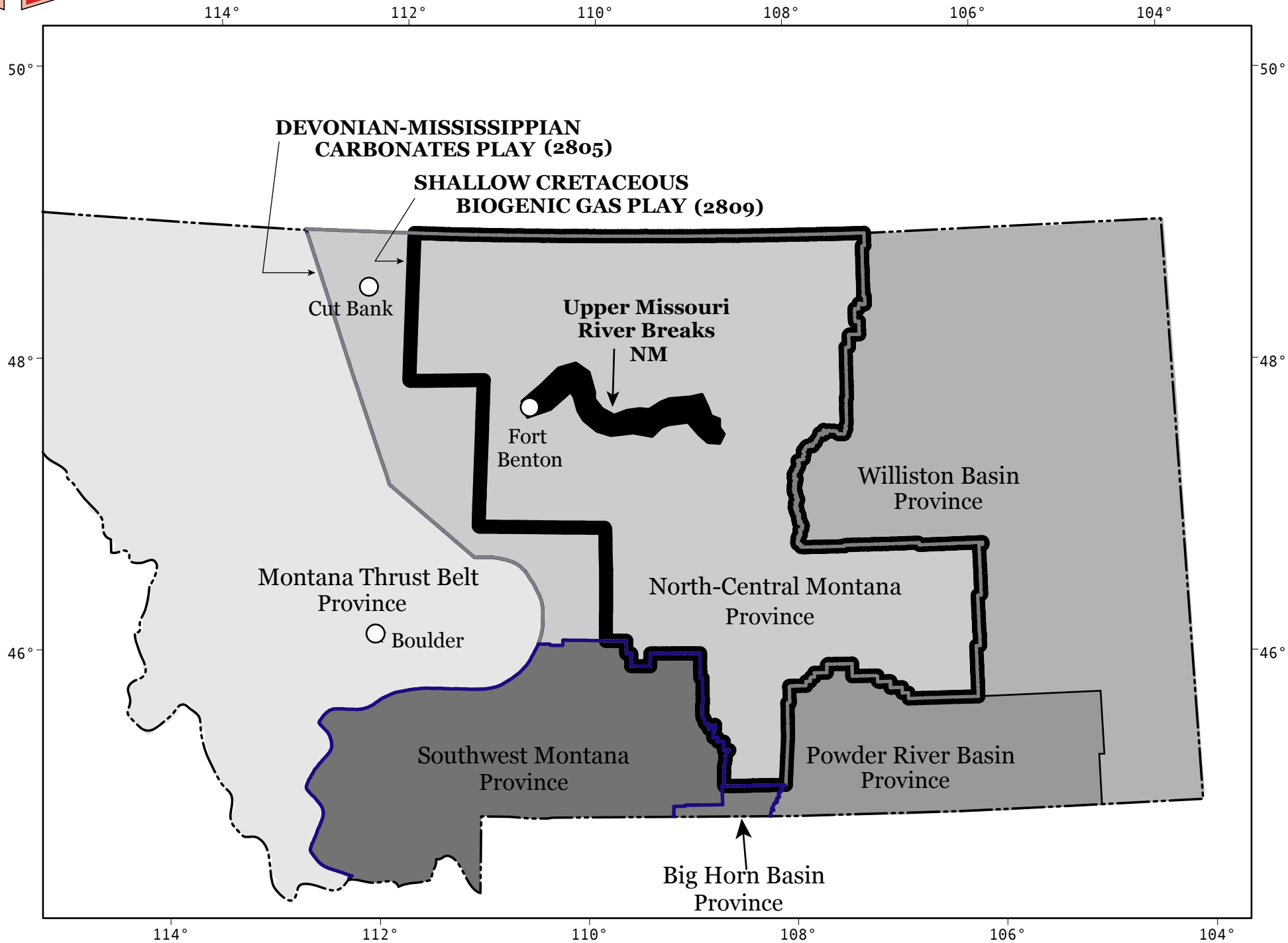

Figure 19. Map showing the location of Upper Missouri River Breaks National Monument, Montana. The Monument overlies several oil and gas plays.

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Vermillion Cliffs National Monument, Arizona

Location and Description

Vermilion Cliffs National Monument, established on November 9, 2000, encompasses 293,000 acres of the Colorado Plateau in northern Arizona (Figure 20). Vermilion Cliffs National Monument borders the Kaibab National Forest to the west, Glen Canyon National Recreation Area to the east, Utah to the north, and State Highway 89A to the south. The Monument includes the Paria Plateau, the Vermilion Cliffs, and the Paria River Canyon. The Monument is immediately south of Grand Staircase-Escalante National Monument.

Resource Geology

The 1995 USGS Assessment (Gautier and others, 1995) defined one hydrocarbon play in the area of Vermilion Cliffs National Monument. The *Late Proterozoic (Chuar-sourced) and Lower Paleozoic Play (2403)* is a hypothetical play defined on the basis of structural traps that may have been sourced by late Precambrian age Chuar Group source rock. The Chuar Group is estimated to contain gray to black shales with sufficient organic richness to have potentially generated oil and gas. Reservoirs are postulated to be porous sandstones within the Chuar Group, or sandstones in the Lower Paleozoic section. Traps are expected to structural and stratigraphic. Generation and timing of hydrocarbons are unknown, but timing of migration would be critical for this play to be viable given the complex structural history of this area.

Resource Summary

We concluded that the probability for the presence of undiscovered oil and gas resources is very low, and the potential volume of oil and gas resources is small. There is no potential for coal and coal-bed methane (Table 2).

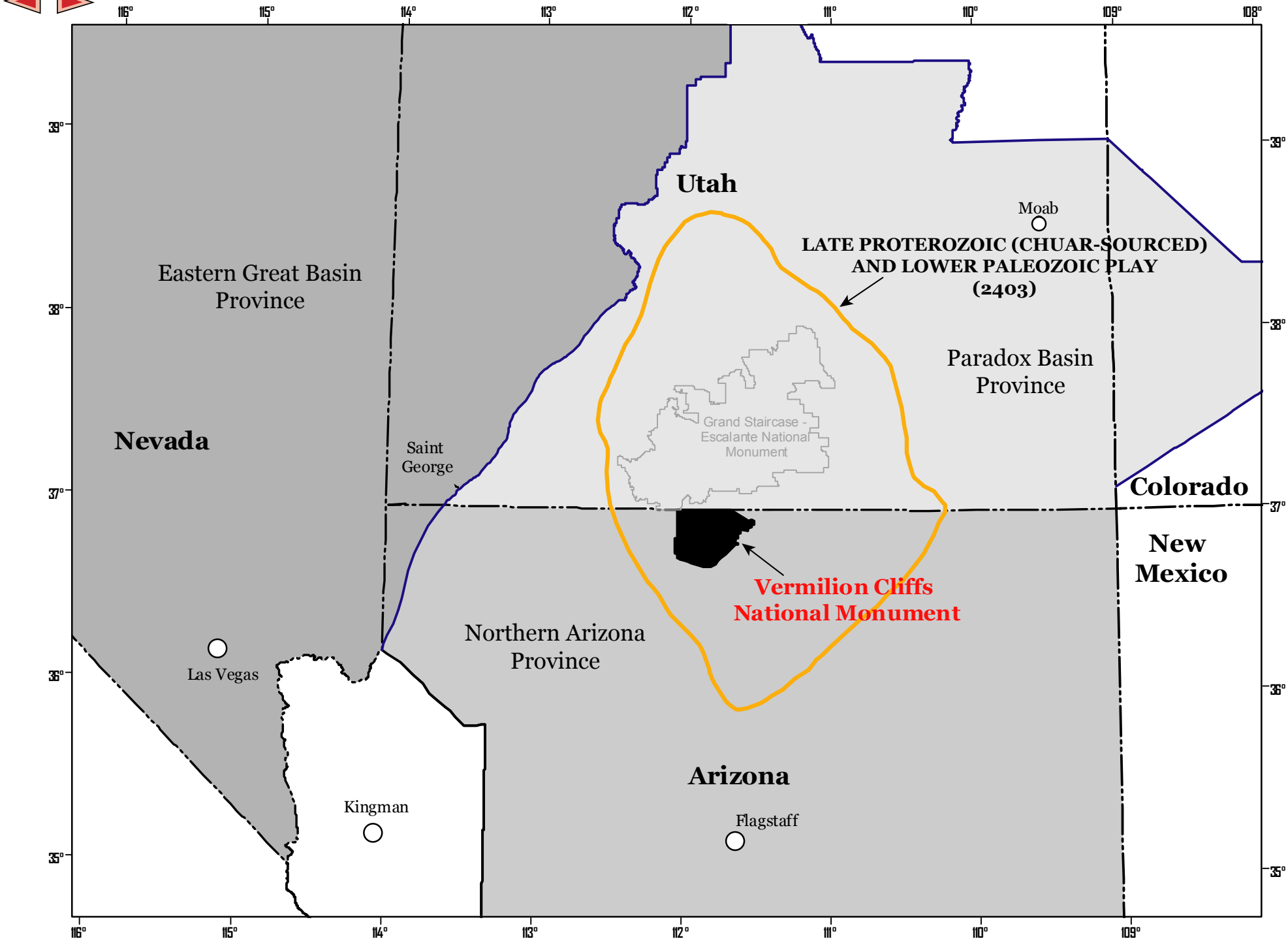

Figure 20. Map showing the location of Vermilion Cliffs National Monument, Arizona. The Monument overlies one hypothetical hydrocarbon play.

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Virgin Islands Coral Reef National Monument, St. Johns, Virgin Islands

Location and Description

The Virgin Islands Coral Reef National Monument, established on January 17, 2001, was created to set aside areas around the existing Virgin Islands National Park, including Hurricane Hole and areas north and south of St. John (Figure 21). The National Monument includes about 12,708 acres of submerged lands within a three-mile belt off the north and south of St. John. Our knowledge of the boundary of this National Monument is very approximate at this time.

Resource Geology

The island of St. John is situated on the Virgin Islands Platform, a feature extending east from the island of Puerto Rico. There are no reports of any potential hydrocarbon source rocks in the vicinity of this area of the Virgin Islands.

Resource Summary

Given the geology of the Virgin Islands Coral Reef National Monument, we concluded that there is no potential for oil, gas, or coal resources within the National Monument (Table 2).

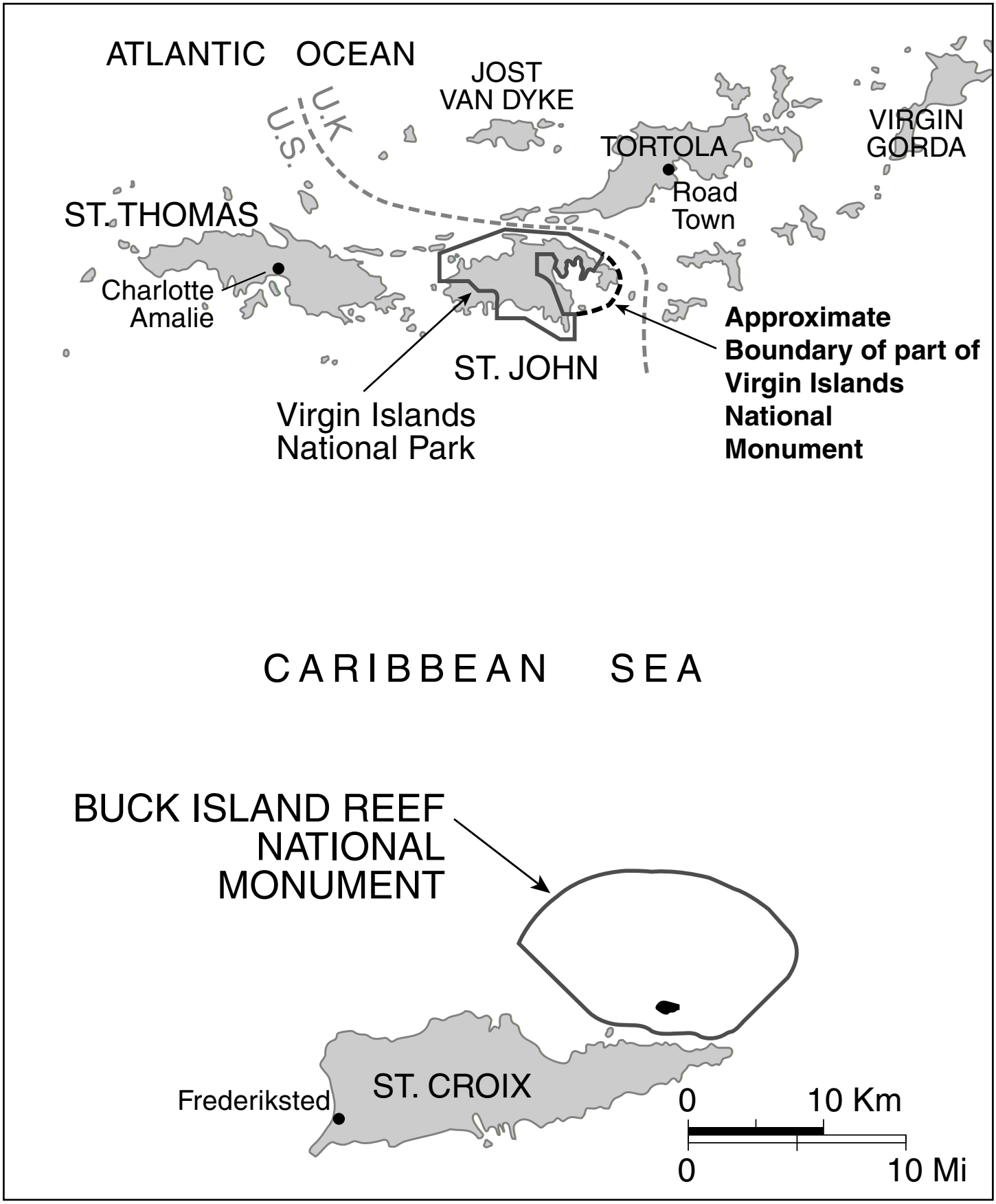

Figure 21. Map showing the location of Virgin Islands Coral Reef National Monument, St. John, U.S. Virgin Islands. The Monument boundary as shown is approximate and incomplete..

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