

U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Plays for assessment in
Region IV, Rocky Mountains and Northern Great Plains
as of October 4, 1993
1995 National Assessment of Oil and Gas

compiled by

D.L. Gautier¹ and K.L. Varnes ¹

Open-File Report 93-596-D

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

¹ U.S. Geological Survey
Denver, Colorado

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The U.S. Geological Survey periodically makes appraisals of the undiscovered oil and gas resources of the Nation. For the 1995 National Assessment the onshore areas and adjoining State waters of the Nation have been divided into eight Regions which are subdivided into 72 provinces. Regions II through VIII comprise the Lower 48 States; Alaska comprises Region I. A map at scale 1:5,000,000 showing the boundaries of Regions II through VIII for this assessment has been released in open file (Dolton, G.L., Varnes, K.L., Gautier, D.L., and Baird, J.K. compilers, 1992, Oil and gas assessment areas, 1992, Lower 48 States: U.S. Geological Survey Open-File Report 92-696, scale 1:5,000,000).

The provinces and assigned Province Geologists for Region IV are listed in Table 1. The basic assessment unit is the play. Table 2 lists the plays considered at this time (October 1993) in Region IV, Rocky Mountains and Northern Great Plains. Descriptions of the plays follow; in most cases these descriptions are written by the indicated Province Geologists (Table 1).

Because this National assessment is currently in progress, these listings and descriptions are preliminary. The plays and/or their names may change as work progresses, some plays may be added, and other plays may be dropped. The descriptions may also change. The plays, play names, and descriptions may or may not duplicate plays appraised in previous National assessments.

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Table 1 List of Provinces and Province Geologists in Region IV, Rocky Mountains and Northern Great Plains

Prov.	Province Name	Province Geologist(s)	Telephone No.	Telephone No.
27	Montana Thrust Belt	Perry, W.J.	(303) 236-5767	
28	North-Central Montana	Dyman, T.S.	(303) 236-5730	
29	Southwest Montana	Perry, W.J.	(303) 236-5767	
30	Central Montana	Dyman, T.S.	(303) 236-5730	
31	Williston Basin	Peterson, J.A.	(406) 542-2087	
32	Sioux Arch	Peterson, J.A.	(406) 542-2087	
33	Powder River Basin	Dolton, G.L., and Fox, J.E.	(303) 236-5768	(605) 394-2468
34	Big Horn Basin	Fox, J.E., and Dolton, G.L.	(605) 394-2468	(303) 236-5768
35	Wind River Basin	Fox, J.E., and Dolton, G.L.	(605) 394-2468	(303) 236-5768
36	Wyoming Thrust Belt	Powers, R.B.	(303) 236-5758	
37	Southwestern Wyoming	Law, B.E.	(303) 236-5779	
38	Park Basins	Wandrey, C.J.	(303) 236-5341	
39	Denver Basin	Higley, D.K.	(303) 236-5791	
40	Las Animas Arch	Keighin, C.W.	(303) 236-9231	
41	Raton Basin - Sierra Grande Uplift	Keighin, C.W.	(303) 236-9231	

Table 2. List of plays for consideration, Region IV, Rocky Mountains and Northern Great Plains

Prov.	Play No.	Play Name
27	2700	unassigned
27	2701	Imbricate Thrust
27	2702	Bakken-equivalent Unconventional
27	2703	Cone Calcareous Member, Marias River (Greenhorn Equivalent) Oil
27	2704	Helena Salient (Belt Embayment)
27	2705	Blacktail Salient Oil
27	2706	Tertiary Basins
28	2800	unassigned
28	2801	Proterozoic
28	2802	Cambrian-Ordovician Sandstones
28	2803	Red River Carbonates
28	2804	Bakken Shale Fracture Systems
28	2805	Devonian-Mississippian Carbonate
28	2806	Tyler Sandstone
28	2807	Fractured-faulted Carbonates in Anticlines
28	2808	Jurassic-Lower Cretaceous Sandstones
28	2809	Cone Member
28	2810	Shallow Cretaceous Biogenic Gas
28	2811	Coalbed Methane
29	2900	unassigned
29	2901	Crazy Mountains Basin (Belt Embayment) Gas
29	2902	Lake Basin Wrench Zone Gas
29	2903	Nye-Bowler Wrench Zone Oil and Gas
29	2904	Beartooth Frontal Zone
29	2905	Madison Subthrust
29	2906	Snowcrest-Greenhorn Subthrust
29	2907	Tertiary Basins Tight Gas
29	2908	Basement Structure
30	3000	unassigned
30	3001	Proterozoic Rocks
30	3002	Cambrian-Ordovician Sandstones, Combination Traps
30	3003	Red River Carbonates, Diagenetic and Facies Seals, Structural Enhancement
30	3004	Devonian-Mississippian Carbonate Facies, Diagenetic and Facies Seals, Paleokarst, Some S
30	3005	Pennsylvanian Tyler Fluvial/Deltaic (Valley-Fill) Sandstone Channels, Structurally Enhanced
30	3006	Fractured/Faulted Carbonates in Anticlinal Traps
30	3007	Jurassic/Lower Cretaceous Predominantly Sandstones in Facies Traps with Structural Enh:
30	3008	Shallow Cretaceous Biogenic/Thermal Gas From Primarily Shelf Sandstones and Siltstones,

Table 2. List of plays for consideration, Region IV, Rocky Mountains and Northern Great Plains

30	3009	Coalbed Methane
31	3100	unassigned
31	3101	Madison (Mississippian)
31	3102	Red River (Post-Winnipeg Upper Ordovician)
31	3103	Middle and Upper Devonian (Pre-Bakken - Post-Prairie Salt)
31	3104	Bakken
31	3105	Pre-Prairie Middle Devonian and Silurian
31	3106	Post-Madison to Triassic Clastics
31	3107	Deep Basin Gas and Condensate
31	3108	Tertiary to Jurassic Coalbed Methane and Biogenic Gas
32	3200	unassigned
32	3201	Cretaceous Gas
32	3202	Truncated Paleozoic
33	3300	unassigned
33	3301	Basin Margin Subthrust
33	3302	Basin Margin Anticline
33	3303	Leo Sandstone
33	3304	Upper Minnelusa Sandstone
33	3305	Lakota Sandstone
33	3306	Dakota Sandstone
33	3307	Muddy Sandstone
33	3308	Mowry Fractured Shale
33	3309	Deep Frontier Sandstone
33	3310	Turner Sandstone
33	3311	Niobrara Fractured Shale
33	3312	Sussex-Shannon Sandstones
33	3313	Mesaverde-Lewis Sandstone
33	3314	Paleocene-Eocene Coalbed Methane
33	3315	Biogenic Gas
34	3400	unassigned
34	3401	Basin Margin Subthrust
34	3402	Basin Margin Anticline
34	3403	Deep Basin Structure
34	3404	Tertiary - Upper Cretaceous Basin Center Gas
34	3405	Sub-Absaroka
34	3406	Phosphoria
34	3407	Tensleep Paleotopography
34	3408	Greybull-Cloverly Sandstone
34	3409	Coalbed Methane

Table 2. List of plays for consideration, Region IV, Rocky Mountains and Northern Great Plains

34	3410	Bighorn-Darby Wedge-edge Pinchout
34	3411	Flathead-Lander and Equivalent Sandstone
34	3412	Madison Limestone
34	3413	Darwin-Amsden Sandstone
34	3414	Triassic and Jurassic Stratigraphic Traps
34	3415	Shallow Structural Tertiary Gas
34	3416	Cody and Frontier Stratigraphic
34	3417	Tertiary-Upper Cretaceous Stratigraphic
35	3500	unassigned
35	3501	Basin Margin Subthrust
35	3502	Basin Margin Anticlinal
35	3503	Deep Basin Structure
35	3504	Muddy Sandstone
35	3505	Tertiary - Upper Cretaceous Basin Center Gas
35	3506	Phosphoria
35	3507	Sub-Absaroka
35	3508	Coalbed Methane
35	3509	Bighorn-Darby Wedge-edge Pinchout
35	3510	Flathead-Lander and Equivalent Sandstone
35	3511	Madison Limestone
35	3512	Darwin-Amsden Sandstone
35	3513	Triassic and Jurassic Stratigraphic Traps
35	3515	Tertiary - Upper Cretaceous Stratigraphic
35	3517	Tertiary-Upper Cretaceous Stratigraphic
35	3518	Tertiary-Upper Cretaceous Basin Center Gas
36	3600	unassigned
36	3601	Moxa Arch Extension
36	3602	Crawford-Meade Thrust
36	3603	Northern Thrusts
36	3604	Absaroka Thrust Gas
36	3605	Absaroka Thrust Oil
36	3606	Hogsback Thrust
36	3607	Cretaceous Stratigraphic
37	3700	unassigned
37	3701	Rock Springs
37	3702	Cherokee
37	3703	Axial
37	3704	Moxa Arch-LaBarge
37	3705	Basin Margin Anticline

Table 2. List of plays for consideration, Region IV, Rocky Mountains and Northern Great Plains

37	3706	Subthrust
37	3707	Platform
37	3708	Jackson Hole
37	3709	Deep Basin
37	3710	Tight Gas
37	3711	Coalbed Methane
37	3713	Absaroka
38	3800	unassigned
38	3801	Cretaceous and Upper Jurassic and Structural
38	3802	Subthrust
38	3803	Fractured Niobrara Formation(horizontal drilling)
38	3804	Coalbed Methane
39	3900	unassigned
39	3901	Sandstones of the Pierre Shale
39	3902	Fractured Shale
39	3903	Niobrara Limestone Gas
39	3904	Codell Sandstone
39	3905	Dakota Group (Comb. J and D Sandstones)
39	3906	J Sandstone Deep Gas
39	3907	Lyons Sandstone
39	3908	Wolfcamp
39	3909	Pennsylvanian
39	3910	Subthrust Structural
40	4000	unassigned
40	4001	Upper Pennsylvanian (Virgilian)
40	4002	Pennsylvanian (Missourian)
40	4003	Pennsylvanian (Desmoinesian)
40	4004	Lower Pennsylvanian (Morrowan)
40	4005	Mississippian (Meramecian/Osagean)
41	4100	unassigned
41	4101	Upper Cretaceous-Lower Tertiary Gas

Descriptions of Plays to be Considered
Region IV, Rocky Mountains and Northern Great Plains

Province 27. Montana Thrust Belt

Play 2701 Imbricate Thrust

This play, in the Montana disturbed belt, north of Lewis and Clark line, extends from the eastern limit of major down-to-west Tertiary normal faulting east to the eastern limit of significant thrust faulting and north to the International Border. Potential source rocks include Cretaceous Marias River Shale, Jurassic black shales of the Ellis Group and the oil-prone Devonian Exshaw Shale. Permian Phosphoria and Late Mississippian Heath to the south may contribute hydrocarbons to the southern edge of the play.

Traps and reservoirs are expected primarily in fractured Devonian to Mississippian carbonate rocks, primarily Mississippian Sun River Dolomite possibly in thrust contact with Cretaceous source rocks. This is a gas play throughout with possible oil potential to southeast. CO₂-rich gas predominates in British Columbia adjacent to the northwest margin of the play. Production is limited to two small shut-in gas fields; however much of play area is off-limits to exploration.

Play 2702 Bakken-Equivalent Unconventional Oil

This is a conceptual oil play based on horizontal drilling results in other regions. Oil-prone Devonian and Mississippian Exshaw (Bakken-equivalent) source rocks lie in the oil window in the frontal zone of the Montana disturbed belt. Known reservoirs are not in this unit but in Mississippian carbonate rocks (play 2701). Anticipated reservoirs in fractured siltstone beds within the Exshaw. The play is considered nonconventional as the oil has not been expelled from its source and conventional oil-water contacts are not anticipated.

Play 2703 Cone Calcareous Member, Marias River (Greenhorn-Equivalent) Oil

This unconventional oil play in the Montana disturbed belt is based on numerous oil shows in the Cone as well as the one well East Glacier field. Oil-prone source rock occurs in the calcareous Cone Member of the Cretaceous Marias River Shale in the Montana disturbed belt. Oil present in East Glacier and Lake Sherburne areas on east side of Glacier Park. Oil-prone Cretaceous source rocks (particularly Cone) absent

south of Lewis and Clark fault zone. Fractured calcareous shale is anticipated reservoir. This play is conceptual as above (Play 2702), and it is considered nonconventional as the oil has not been expelled from its source and conventional oil-water contacts are not anticipated.

Play 2704 Helena Salient (Belt embayment) Gas

Possible source rocks for this structural conceptual play include black shales of the Middle Proterozoic Chamberlain, Newland, and LaHood Formations, Devonian-Mississippian Bakken-equivalents, Mississippian Heath, Permian Phosphoria, and various Cretaceous organic-rich shales. All rocks sampled to date west of Lombard thrust are highly thermally altered (paleotemperatures >200° C). Anticipated reservoir rocks include Paleozoic sandstones and carbonates and Cretaceous sandstones with fracture-enhanced porosity.

Anticipated structural traps are associated with Lombard thrust and anticlines of frontal zone to the east throughout Phanerozoic/Middle Proterozoic sequence. Large areas of play are adjacent to intrusive rocks.

Play 2705 Blacktail Salient Oil

This conceptual play is based on thick source rock section of Bakken-equivalent lower Sappington (Upper Devonian), Heath equivalent shales of the Snowcrest Range Group, Permian Retort Member of Phosphoria in Blacktail Mountains.

Inferred structural traps west of thrust front in Blacktail Mountains, west to Tendoy Mountains and possibly northwestward beneath the Armstead thrust and anticline. Normal faults of Red Rock Valley fault system and Horse Prairie fault system may have disrupted older structural traps.

Play 2706 Tertiary Basins

This conceptual play is based on the presence of numerous Tertiary basins, with source rocks and possible traps. Source rocks include oil shales and a few lignite beds. The Kishenehn basin has demonstrably rich oil shales but no known traps. The largest (the Big Hole) basin contains more than 16,000 ft of Tertiary rocks above Middle Proterozoic Belt rocks of Grasshopper thrust plate with good gas shows in two wells. Extensive drilling in the Deer Lodge basin has been unsuccessful.

A few lignitic beds present may provide possibilities for coalbed methane. Fairly large quantities of tight gas may be present in Big Hole

Basin. Zeolite-cemented sandstones above basal unconformity may provided seals for hydrocarbons in underlying rocks (Nevada analog).

Province 28. North-central Montana

Play 2801 Proterozoic Rocks

This conceptual play is considered minor; there are no existing shows or production. No direct information on trapping mechanisms, but in part same as in younger rocks. No available thermal maturity data, but TOC's >1% in thrust belt to west in Prichard Fm; also stromatolites in Helena and Wallace carbonates. May be >20,000 ft thick in central Montana trough and up to 2,000 ft thick here. Play limited to southern part of province. (conceptual)

Play 2802 Cambrian/Ordovician Sandstones

Flathead and Winnipeg sandstones in shallow combination traps. No Cambrian production in Montana, but more than 60 wells penetrated; some oil shows. Facies changes with Laramide and post-Laramide structures enhancing traps. Potential source rocks in Upper Cambrian and Red River shales/carbonates. Winnipeg gas production immediately east of province in Williston basin. (conceptual)

Play 2803 Ordovician Carbonates

Diagenetic and facies seals, structural enhancement. Carbonate/evaporite cycles, carbonate buildups. Traps may be enhanced by Laramide/post Laramide structures. Existing Red River production east of province at Putnam field, and oil shows within province. Ordovician carbonates absent on Sweetgrass arch (west half of province). Source rocks primarily in Red River shales. Low potential because Ordovician carbonates are thinner than in Williston basin. (conceptual)

Play 2804 Fractured Bakken Shale

Although discontinuously present within province, Bakken could produce HC's as in Williston basin, particularly with horizontal drilling practices. Generally only locally thermally mature east of the westernmost part of the province. Local hot spots may produce oil elsewhere. Source rocks within Bakken; reservoir rocks include siltstones and fractured shales within Bakken. Isopach maps have been used to define play extent. Becomes part of Devonian-Mississippian carbonates play in central Montana. (conceptual)

Play 2805 Devonian/Mississippian Carbonates

This play is defined by carbonate facies, diagenetic and facies seals, paleokarst, and structural enhancement. It involves carbonate/evaporite cycles, carbonate buildups (including Walsortian mounds) in Nisku, Madison, Three Forks. Traps may be enhanced by Laramide/post Laramide structures. Best source rocks include Bakken, Three Forks, and Heath Fms. Bakken absent from area of central Montana uplift (trough). Pondera and East Kevin fields representative of play. Recent interest in horizontal drilling (Madison) may enhance this mature play.

Play 2806 Tyler Sandstone

This play is limited to southern part of province in central Montana trough in Pennsylvanian Tyler fluvial/deltaic (valley -fill) sandstone channels, structurally enhanced. This structural enhancement of valley-fill reservoirs is associated with Laramide and post-Laramide folding/faulting. Thermally mature with respect to oil. (conceptual)

Play 2807 Fractured/Faulted Carbonates In Anticlinal Traps

Pennsylvanian Amsden and Devil's Pocket Fms. and Mississippian Heath Fm., but also includes Jurassic Rierdon and Piper (Sawtooth) and Cretaceous Greenhorn and Niobrara carbonates. Fractured reservoirs associated with Laramide anticlines and domes. Oil source may vary, particularly when strongly faulted but includes possible Heath, Tyler, Madison, and lower Paleozoic sources. Big Wall field produces from fractured dolomites in the Amsden associated with an anticlinal trap (this play), as well as from Tyler sandstones which are stratigraphically and structurally trapped. Cat Creek field produces from strongly fractured Jurassic Piper and Amsden in association with Laramide domes (Mosby and East domes) and intense faulting. Production from highly fractured Heath shaly limestone along flank of anticline at Devil's Pocket field immediately south of province.

Subplay 2807a Cone Member Marias River Shale/Greenhorn

Horizontal drilling, west flank Sweetgrass arch (conceptual)
Carbonates and calcareous shales with fractures- internally sourced primarily along western margin of province near Disturbed belt. Cone Member reaches 2.4 wt percent TOC in western part of province (Clayton et al., 1982). No production within province but oil production from East Glacier field in Disturbed belt to west. Fracture systems associated with Laramide and post-Laramide structures. Regionally higher thermal gradients and greater burial depths in west.

Play 2808 Coalbed Methane

Methane from coal beds in Cretaceous rocks. Much of north-central Montana contains variably thick coal beds capable of methane production. No present production in north-central Montana. (conceptual)

Play 2809 Jurassic/Lower Cretaceous

Predominantly fluvial/deltaic sandstones in facies traps with structural enhancement

Sawtooth, Swift, Rierdon, Morrison, Kootenai, Blackleaf, and Marias River Fms. as reservoirs. Reservoirs separated by major unconformities. Mature production and well-drilled play since early 1900's; originally based on seeps. Facies traps including valley-fill sequences in fluvial to shallow marine sandstones with updip closure on Laramide anticlines; some fault enhancement. Some facies variations in limestones also part of this play such as Sawtooth carbonate pinchouts in Rabbit Hills field. Probably Bakken source based on recent work by Dolson et. al., 1992, but also possibly Tyler, Heath, and lower Paleozoic sources. Cretaceous source rocks generally at or below oil generation window. Local heat sources such as Sweetgrass Hills volcanics will locally generate Cretaceous oil. Cutbank field representative of play.

Play 2810 Shallow Cretaceous

Biogenic/thermal gas from primarily shelf sandstones and siltstones, fracture systems and Laramide and post Laramide structures (low-permeability gas component)-Rice and Shurr during 1970's defined boundaries of province and established facies. Mowry, Belle Fourche, and Carlile Shales; Niobrara and Greenhorn Formations; Telegraph Creek Formation, Eagle Sandstone, and Judith River Formation, and to a lesser extent, the Bearpaw Shale and Fox Hills Sandstone. Primarily internally-sourced biogenic gas, 95+% methane, although some mixing with thermal gas in fractured areas and areas of Laramide structures. Fracture porosity very important but also tied to Laramide doming (Bowdoin Dome field) and post-Laramide gravity sliding (Tiger Ridge field). Depth range from 500 to about 4,000 feet. intensity of fracturing not fully understood- may be tied to regional lineaments. Shelf sandstones and siltstones encased in shales are best reservoir rocks. Crest of Bowdoin is conventional biogenic because a gas-water contact is present and permeabilities reach up to 0.7 md. Battle Creek field Niobrara reservoir is considered low-permeability according to James Halvorson (Montana Oil and Gas Conservation Commission). Tiger Ridge field is not low-permeability but is biogenic.

Province 29. Southwest Montana

Play 2901 Crazy Mountains Basin (Belt Embayment) Gas

Possible Middle Proterozoic source rocks include black shales associated with the LaHood Fm to the west and Chamberlain Shale and Newland Formation to north. Possible very high paleotemperature exposure (~200°C) is based on mineralogy of chlorite (clinochlore IIB), RockEval and vitrinite reflectance data to the west. No to thin Bakkan-equivalent Devonian source rocks are present. Potential Mississippian source rocks include lower Madison Lodgepole Formation and Late Mississippian Heath Formation. Anticipated gas-prone Cretaceous source rocks, including Thermopolis, Cody and Mowry shales. Coalbed methane may be present in the eastern part of the play area.

Possible reservoirs include Lower Mississippian Walsortian mounds, sink-holes and zones of karstic porosity in the Madison Group as well as Late Mississippian, Pennsylvanian and Permian sandstones. Paleozoic rocks are deeply buried in the western part of the basin. Numerous Cretaceous rocks have reservoir potential. One small gas field is present in the northeastern part of play area. Subtle combination traps may be present. This play is chiefly conceptual.

Play 2902 Lake Basin Wrench Zone Gas

Cretaceous source rocks are present. Possible Paleozoic and Proterozoic source rocks as in Play 2901. Demonstrated reservoir rocks are Cretaceous; possible Paleozoic reservoirs may be present as in play 2901. Several small gas fields are present near the eastern edge of the play. Structural traps are represented by en echelon anticlines and bounding faults.

Play 2903 Nye-Bowler Wrench Zone Oil And Gas

Cretaceous and older source rocks are present. Migration of Phosphoria oil from farther west and south? into play area may have occurred prior to growth of Beartooth uplift. Reservoirs and seals are primarily in Cretaceous rocks in en echelon faulted anticlines. Dry Creek oil field (4.1 MMBO produced to 1/01/90) and Golden Dome gas storage field are the largest fields. All known surface closures have been drilled. Roscoe, MacKay, Fiddler Creek, and Dean Dome heavy oil "fields" north of Beartooth front are shut-in or abandoned.

Play 2904 Beartooth Frontal Zone

Cretaceous and older source rocks are present. Presence of Permian Phosphoria-sourced hydrocarbons evidenced by the Cruse oil seeps. Phosphoria oil likely migrated into area prior to formation of the

Beartooth uplift. Reservoirs are expected in fractured Paleozoic and Cretaceous rocks in subtle traps sealed beneath Beartooth thrust.

Play 2905 Madison Subthrust

Cretaceous and older potential source rocks are present. Migration of Phosphoria oil into area prior to formation of the Madison-Gravelly uplift may have occurred. Structures associated with the Hilgard thrust system may form possible footwall traps. This play is conceptual; there is no current or past hydrocarbon production.

Play 2906 Snowcrest-Greenhorn Subthrust

Possible source rock includes primarily organic-rich mudstones of the Permian Phosphoria Formation and secondarily shales of the Bakken-equivalent Sappington Member of the Upper Devonian Three Forks Formation. Footwall rocks are primarily supermature with respect to oil generation. Hanging-wall rocks lack obvious seals. A gravity low beneath Lima Peaks, inferred extension of the Snowcrest thrust system beneath front of Montana thrust belt suggests the possibility of hydrocarbon traps in western part of play area. This play is conceptual; there is no current or past hydrocarbon production.

Play 2907 Tertiary Basins (Tight-Gas)

Possible source rocks (oil shales and/or lignite) may be locally present in deeper parts of basins. The Jefferson, Madison, and Sage Creek basins have no demonstrated hydrocarbon potential. Tertiary rocks in these basins generally rest on Precambrian gneiss. Possible reservoir sands are admixed with volcanoclastic material; effective porosity is likely reduced by zeolite cementation. This play is conceptual; there is no current or past hydrocarbon production.

Play 2908 Basement Structure

This play includes the Big Sky and Ruby basins as well as part of the Neogene Centennial uplift, originally part of the Ruby basin. Cretaceous and older possible source rocks are present. Possible subtle structural traps may exist in these Laramide foredeep basins. Migration of Phosphoria oil from farther west and south? into the play area may have occurred prior to growth of these Laramide basins and uplifts. This play is conceptual; there is no current or past hydrocarbon production.

Province 30. Central Montana

Play 3001 Proterozoic Rocks

No existing shows or production, but play may have considerable potential if source rocks are present. No direct info on trapping mechanisms, but in part same as in younger rocks. TOC's >1% in thrust belt to west in Prichard Fm; also stromatolites in Helena and Wallace carbonates. Local interest in black organic-rich carbonates on east side of Belt basin. May be >20,000 ft deep in the westernmost part of the central Montana trough. Play boundary based on approximate position of 5,000 ft thickness contour. Best potential in western part of province. (conceptual)

Play 3002 Cambrian-Ordovician Sandstones, Combination Traps

Flathead, Winnepeg, and equivalent sandstones. No Cambrian production in Montana, but more than 60 wells penetrated; some oil shows. Facies changes with Laramide and post-Laramide structures enhancing traps. Potential source rocks in Proterozoic, Upper Cambrian, and Red River shales/ carbonates. Winnepeg gas production east of province in Williston basin. (conceptual)

Play 3003 Red River Carbonates, Diagenetic And Facies Seals, Structural Enhancement

Carbonate/evaporite cycles, carbonate buildups. Traps may be enhanced by Laramide/post Laramide structures. Existing Red River production east of province at Putnam field. Ordovician carbonates absent in northwestern part of province. Source rocks primarily in Red River shales. (conceptual)

Play 3004 Devonian/Mississippian Carbonate Facies, Diagenetic And Facies Seals, Paleokarst, Some Structural Enhancement

Carbonate/evaporite cycles, carbonate buildups (including Walsortian mounds in lower Lodgepole) in Three Forks, Big Snowy, Madison. Traps may be enhanced by Laramide/post Laramide structures. Best source rocks include Bakken, Three Forks, and Heath Fms. Bakken absent from area of central Montana uplift (trough). Devil's basin field representative of play. Recent interest in horizontal drilling (Madison) may enhance play.

Play 3005 Pennsylvanian Tyler Fluvial/Deltaic (Valley-Fill) Sandstone Channels, Structurally Enhanced

Structural enhancement of valley-fill reservoirs associated with Laramide and post-Laramide folding/faulting. Big Wall field is representative of play; potential Tyler, Heath, Bakken, Red River

sources. Thermally mature with respect to oil. Small fields but best-developed play in province.

Play 3006 Fractured/Faulted Carbonates In Anticlinal Traps

Pennsylvanian Amsden and Devil's Pocket Fms. and Mississippian Heath Fm., but also includes Jurassic Rierdon and Piper (Sawtooth) and Cretaceous Greenhorn and Niobrara carbonates. Fractured reservoirs associated with Laramide anticlines and domes. Oil source may vary, particularly when strongly faulted but includes possible Heath, Tyler, Madison, and lower Paleozoic sources. Big Wall field produces from fractured dolomites in the Amsden associated with an anticlinal trap as well as from Tyler sandstones which are stratigraphically and structurally trapped. Production from highly fractured Heath shaly limestone along flank of anticline at Devil's Pocket field immediately south of province.

Play 3007 Jurassic/Lower Cretaceous Predominantly Sandstones In Facies Traps With Structural Enhancement

Sawtooth, Swift, Rierdon, Morrison, Kootenai, Thermopolis, etc. Fms. as reservoirs. Reservoirs separated by major unconformities. Facies traps including valley-fill sequences in fluvial to shallow marine sandstones with updip closure on Laramide anticlines; some fault enhancement. Possibly Tyler, Heath, and lower Paleozoic sources. Cretaceous source rocks generally at or below oil generation window. Mason Lake field representative of play (Cat Creek sands of drillers use). Not as well developed play as in north-central Montana province.

Play 3008 Shallow Cretaceous Biogenic/Thermal Gas From Primarily Shelf Sandstones and Siltstones, Fracture Systems and Laramide and Post Laramide Structures

Mowry, Belle Fourche, and Carlile Shales; Niobrara and Greenhorn Fms; Telegraph Creek Formation, Eagle Sandstone, and Judith River Formation, and to a lesser extent, the Bearpaw Shale and Fox Hills Sandstone. Predominantly Cretaceous reservoir rocks, although some data suggest that Jurassic rocks may be involved. Primarily internally-sourced biogenic gas. 95+% methane, although some mixing with thermal gas in fractured areas and areas of Laramide structures. Significant low-permeability gas component. (conceptual)

Play 3009 Coalbed Methane

Methane from coal beds in Cretaceous rocks. Much of south-central Montana contains variably thick coal beds capable of methane production. No present production in south-central Montana. (conceptual)

Province 31. Williston Basin

Play 3101 Madison (Mississippian)

Play is based on structural and stratigraphic drape folds in defined intervals (cycles) of porous carbonate reservoirs interbedded with non-porous carbonate facies and overlain by evaporite seals with a sequence of major regional seals (Charles salt) at the top of the Madison. Source rocks are organic-rich marine shales and shaly carbonates interbedded with carbonate reservoir units, or similar shales in the lower Lodgepole and Bakken Formations.

Play 3102 Red River (Post-Winnipeg Upper Ordovician)

The play is based on cycles of carbonate, evaporite, and organic-rich shale source beds in the upper part of the Red River Formation and overlying beds. Traps are on major and minor anticlines, and drape folds associated with carbonate bank buildups.

Play 3103 Middle And Upper Devonian (Pre-Bakken - Post-Prairie Salt)

Play is based on structural and stratigraphic traps in mainly Upper Devonian carbonate-evaporite-dark marine shale cycles, some with reefoid buildups. Source rocks are dark marine shaly beds interbedded with porous carbonate reservoirs.

Play 3104 Bakken

Play is based on the occurrence of limy organic-rich source rock shale and siltstone fractured reservoirs on the fringes of the Bakken depositional basin. Traps are on anticlines, trends in updip pinchouts, and in overpressured belts.

Play 3105 Pre-Prairie Middle Devonian and Silurian

Play is based on structural and stratigraphic traps in Middle Devonian and Silurian carbonate reservoir units, in some cases reefs, below a regional seal, the Prairie evaporite. Source rocks are Upper Ordovician and Middle Devonian shaly beds and organic-rich shales of the upper Red River Formation.

Play 3106 Post-Madison to Triassic Clastics

Play is based on structural and stratigraphic traps in Pennsylvanian-Upper Mississippian alluvial and deltaic clastic and minor carbonate reservoir facies of the Big Snowy, Amsden, and Tyler Formations. The main source beds are associated organic-rich shales of the Tyler and Heath Formations.

Play 3107 Deep Basin Gas and Condensate

Play is based on the occurrence of Ordovician and Cambrian sandstones and carbonate reservoirs of the Deadwood, Winnipeg, and Red River Formations, mainly below 12,000 ft depth, in the basin interior. Source rocks are dark marine shales of the upper Deadwood, Winnipeg, and upper Red River Formations. Traps are major anticlines, small folds, and isolated sandstone, quartzite, or carbonate bodies in fracture-intensive areas.

Play 3108 Tertiary to Jurassic Coalbed Methane and Biogenic Gas

Play is based on the widespread occurrence of continental, lacustrine, and marine sandstone reservoirs of Jurassic, Cretaceous, and Tertiary ages associated with Mesozoic and early Tertiary carbonaceous and coaly source beds. Traps are discontinuous sandstones and siltstones, many are tight sands, and coal or lignite beds.

Province 32. Sioux Arch

Play 3201 Cretaceous Gas

An unconventional biogenic gas play basically on the southern updip flank of the Williston basin. Reservoirs are sandstones and marine chalk of Cretaceous age. Source rocks are Upper Cretaceous shales and chalky beds. Traps are minor folds and lensing or updip stratigraphic traps.

Play 3202 Truncated Paleozoic

Play is based on the subsurface belt of pinching out and truncated Madison and Red River carbonates around the outer fringes of the Sioux arch. Traps are updip pinchouts and/or small folds, sealed by onlapping Cretaceous shaly beds. Source rocks are Paleozoic marine shales present to the north in the Williston basin.

Province 33. Powder River Basin

Play 3301 Basin Margin Subthrust

The subthrust play describes the occurrence of petroleum trapped in deformed strata below major thrusts which are located along the basin margins. The overthrust wedge of Precambrian rocks may act as a trap and seal of fluids in the underlying sedimentary wedge, or may simply conceal traps which have formed in underlying folds or faults. This is a hypothetical play, although productive in the adjacent Wind River basin. Reservoirs range in age from Mississippian to Upper Cretaceous and include sandstones, carbonates and occasional fractured shales.

Play 3302 Basin Margin Anticline

This play is characterized by oil and gas accumulations trapped in large and small anticlines along the southern and western margins of the basin. The majority of the anticlines are relatively simple folds which are reverse-faulted at depth but with extensional faults on their crests. Fault closures, particularly on plunging anticlinal noses also produce, as do combination traps. Reservoirs range in age from Mississippian to Upper Cretaceous and include sandstones, carbonates and occasional fractured shales.

Play 3303 Leo Sandstone

The Leo play is characterized by the occurrence of oil in stratigraphic traps in quartzose sandstones of the Leo Sandstone member of the Minnelusa Formation, in the southern part of the basin. Traps are subtle and include primarily sandstone pinchouts or gradations into impermeable facies.

Play 3304 Upper Minnelusa Sandstone

This play is based on the occurrence of oil in stratigraphic accumulations which are largely related to paleotopography, reservoir truncation, and sandstone pinchouts at the top of the Minnelusa Formation. The play is located on the broad, gently sloping eastern flank and central portion of the Powder River basin in areas containing well-developed eolian sandstone reservoirs of Permian age. The play appears to be somewhat limited to the south by the widespread occurrence of evaporites which adversely effect hydrocarbon migration and reservoir quality. The play is located on the east flank of the Powder River basin.

Play 3305 Lakota Sandstone

This play is characterized by the occurrence of oil in stratigraphic traps of the basal Inyan Kara Group in the structurally uncomplicated portions of the basin. The traps are invariably within discrete or composite channel sandstones of alluvial or deltaic origin and are sealed by fine-grained alluvial non-marine sediments. These traps also occur in combination with structural noses or anticlinal closures outside of the play area.

Play 3306 Dakota Sandstone

This play is characterized by oil and gas occurrence in stratigraphic traps within the regressive clastic wedge of the Fall River Formation (Dakota Sandstone) of the Lower Cretaceous Inyan Kara Group. This widespread clastic wedge prograded into the Western Interior Seaway from the south and east and it is composed of a marine, deltaic and

alluvial complex which becomes progressively more marine to the west, where it consists entirely of marine shales and siltstones of the Thermopolis Shale.

Play 3307 Muddy Sandstone

This play describes the occurrence of oil and gas in stratigraphic traps of the Lower Cretaceous Muddy-Newcastle Sandstone complex of the basin and is characterized by a suite of trap types related to varied depositional environments. The play area covers much of the Powder River basin.

Play 3308 Mowry Fractured Shale

This play is defined by the occurrence of oil and gas in fractured Mowry shale reservoirs in the deeper parts of the basin. The highly fractured shale is considered both a reservoir and source. Controls on the origin and distribution of fracturing in the Mowry Shale are not certain, although several workers have proposed geopressuring associated with thermal maturation of the organic matter and attendant phase and volume changes. The play occupies the central part of the basin.

Play 3309 Deep Frontier Sandstone

This play involves the occurrence of oil and gas in stratigraphic traps in offshore marine shelf sandstones of the Upper Cretaceous Frontier Formation in large, high-energy bar complexes, located in the deeper parts of the present basin. The play covers an area in the central and southern part of the Powder River basin.

Play 3310 Turner Sandstone

This play is defined by the occurrence of oil and gas in stratigraphic traps in offshore marine shelf sandstones of the Turner Sandstone Member of the Carlile Shale on the shallow east flank of the basin.

Play 3311 Niobrara Fractured Shale

This play is defined by the occurrence of oil and associated gas in fractured shale reservoirs of the Niobrara Formation. Reservoirs are fractured shale within the formation. Controls on fracturing are not well understood. In some instances, fractures appear localized or enhanced on structural flexures, including some large anticlines and major faults. Geopressuring associated with thermal maturation of the organic matter and attendant phase and volume change have been proposed as a causative factor.

Play 3312 Sussex-Shannon Sandstone

This play encompasses hydrocarbon accumulations in stratigraphic traps in the Sussex and Shannon Sandstone Members of the Cody Shale. These two units are interpreted to have been deposited as parts offshore bar complexes and are the result of residual sand sheets on the shelf being transported and formed into broad, elongate sandstone bodies or offshore bars by marine currents. The play covers an area in the deeper part of the basin.

Play 3313 Mesaverde-Lewis

This play involves oil and gas occurrence in stratigraphic traps in marine sandstones of the Upper Cretaceous Mesaverde Formation and Lewis Shale. Strata involved in this play are part of a large western-derived regressive clastic sequence and include deltaic and marine shelf sandstone members that grade into siltstone or shale. Deltaic sands deposited in a wave-dominated high-destructive shoreline environment, locally modified into offshore bars, produce the primary reservoirs and traps for hydrocarbons. The play area is an elongate, northwesterly trend in the deeper, central part of the basin.

Play 3314 Paleocene-Eocene Coalbed Methane

Coal bearing rocks of the Fort Union formation and lower Eocene, which occupy a large central area of the basin constitute an important resource for coalbed gas.

Play 3315 Biogenic Gas

This play encompasses biogenically generated gas trapped in conventional stratigraphic and structural traps in the Tertiary and Cretaceous sequence. It resides generally above and beyond the limits of thermally mature source beds and their migrated hydrocarbons. It involves virtually the entire Cretaceous and Fort Union sequence in Montana, rising stratigraphically southward to include principally uppermost Cretaceous rocks and Tertiary beds.

Province 34. Big Horn Basin

Play 3401 Basin Margin Subthrust

Laramide basin-margin thrusting has trapped oil and gas in upturned, overturned, folded, and faulted Phanerozoic strata below the overthrust wedge. Reservoir formations can be any age or lithotype with porosity, often enhanced by fracturing. Principal reservoirs are Cretaceous and Pennsylvanian sandstones and Permian, Mississippian, and Devonian carbonates. Early (pre-Laramide) generation and migration hydrocarbons from the Phosphoria Formation to the west

may have occurred, followed by a later (Laramide) stage of migration and generation from Cretaceous source rocks at about the same time as structures were developing.

Play 3402 Basin Margin Anticline

Oil and gas is trapped in anticlines and associated structures that formed along the shallow margins of the basin during the Laramide orogeny. Producing formations range in age from Cambrian to Late Cretaceous, with primary production from both carbonate and clastic rocks of the Madison, Tensleep, Phosphoria, and Frontier formations, often occurring in fields as multiple pay zones. Indigenous oil-prone source rocks occur primarily in mid-Cretaceous and Permian strata including the Mowry and Phosphoria formations.

Play 3403 Deep Basin Structure

Primarily gas is trapped in large intrabasin anticlinal and fold nose structures within the deep (to about 17,000 ft) central portion of the basin. Productive reservoirs occur in Paleozoic (Phosphoria and Tensleep formations) and Cretaceous (Muddy and Frontier formations) strata, primarily sandstones and may occur in Mississippian and older carbonate reservoirs. Indigenous source rocks occur primarily in marine Phosphoria shales and marine and paludal shales of the Cretaceous Thermopolis, Mowry, Frontier, Cody and Mesaverde formations.

Play 3404 Tertiary-Upper Cretaceous Basin Center Gas

Gas trapped in a major basin center accumulation in deep parts of the basin in Paleocene and uppermost Cretaceous sandstone reservoirs. Principal formations are Fort Union, Lance and Mesaverde. The play is characterized by a regional accumulation of gas resulting from low reservoir permeability and overpressuring due to active gas generation. Reservoirs are sandstones. Older Cretaceous rocks, which may also be geopressed, are not considered because of generally thin reservoir development and limited reservoir volumes. Sandstones, particularly localized channel bodies of limited extent, provide internal compartmentalization. Low permeability reservoirs and associated fine grained rocks furnish seals. Source rocks are humic rich rocks and coals. This play is speculative and has seen virtually no meaningful exploration.

Play 3405 Sub-Absaroka

Oil occurs beneath Eocene volcanic rocks, trapped in Laramide anticlines and domes, in many cases faulted and eroded prior to being covered by the volcanics. Structures in the eastern play area are on-

trend with producing structures of the "Basin Margin Anticline" play, which may be representative of structural style and productivity. Productive formations are primarily Paleozoic sandstones and carbonates, with oil locally sourced from mid-Cretaceous and older strata such as the Mowry and Phosphoria formations. Production potential is enhanced by the proximity of the play area to the deep western side of the basin where hydrocarbon generation was most extensive.

Play 3406 Phosphoria

High-sulfur oil is stratigraphically trapped in the Ervay Member of the Phosphoria Formation along a generally north-south trending zone of facies change from Phosphoria carbonates on the west to red shale and evaporites of the Goose Egg Formation on the east. Reservoir rocks of the Ervay are porous and permeable tidally-influenced carbonates, productive to a depth not in excess of about 11,000 ft, sealed updip by tight fine-grained intertidal and supratidal carbonates. Oil was generated from organic-rich source rocks of the Phosphoria Formation.

Play 3407 Tensleep Paleotopography

This hypothetical play encompasses oil and gas stratigraphic traps in the Pennsylvanian Tensleep Sandstone below the Pennsylvanian-Permian erosional paleotopographic surface, which has a relief of more than 150 ft throughout much of the basin area. The play is most prospective in areas of low structural relief where the magnitude of the associated structural dip does not exceed paleoslopes; where it does hydrocarbons may leak out of the trap. Oil was generated from organic-rich rocks of the Phosphoria Formation and may have migrated into the traps before the Laramide Orogeny.

Play 3408 Greybull/Cloverly Sandstone

This play includes oil and gas in stratigraphic traps of the Lower Cretaceous Greybull/Cloverly, within discrete or composite alluvial channel sandstones at depths from about 5,000 to 11,000 ft. Reservoirs are fine to coarse-grained sandstones which are locally pebbly or conglomeratic, sealed by finer-grained associated alluvial facies. Primary source rocks are presumed to be Lower Cretaceous marine shales of the Mowry and Thermopolis.

Play 3409 Coalbed Methane

This play encompasses the occurrence of gas in coals of Upper Cretaceous and Paleocene age. These coals have locally been mined. The play is generally limited to areas of Fort Union, Lance, Meeteetse, and upper Mesaverde formations at relatively shallow depths.

Although occasional thin coals are found in other Cretaceous and Tertiary formations, they are not considered of sufficient quantity to include in the play.

Play 3410 Bighorn-Darby Wedge-Edge Pinchout

This hypothetical play encompasses hydrocarbon occurrence in the wedge-edge or beveled-edge pinchouts of the Ordovician Bighorn Dolomite which abut against the base of the Madison Limestone, providing potential traps. There are no known hydrocarbon occurrences and source rocks are not known.

Play 3411 Flathead-Lander and Equivalent Sandstone

This hypothetical play includes hydrocarbon trapped in stratigraphic pinchouts of the Cambrian Flathead and Ordovician Lander Sandstones.

Play 3412 Madison Limestone

This hypothetical play encompasses oil entrapment within or at the top of the Mississippian Madison Limestone caused by porosity variation and topography related to karst development.

Play 3413 Darwin-Amsden Sandstone

This hypothetical play consists of stratigraphic entrapment of oil in discontinuous sandstones of the Pennsylvanian Darwin and Amsden formations. Although there is no known occurrence of oil in such traps, these formations are productive in structural settings.

Play 3414 Triassic And Jurassic Stratigraphic Traps

This play encompasses stratigraphic traps in the Crow Mountain Sandstone and equivalent(?) Jelm Formation of the Chugwater Group, Sundance Formation, and Morrison Formation. Also, wedge-edge pinchouts and truncations of the Nugget Sandstone.

Play 3416 Cody and Frontier Stratigraphic

Oil and gas accumulations in the Cody and Frontier (Torchlight and Peay) formations in a thick sequence of marine shale and fine-grained sandstone.

Play 3417 Tertiary-Upper Cretaceous Stratigraphic

Gas trapped in stratigraphic and combination traps in Eocene, Paleocene, and uppermost Cretaceous sandstone reservoirs, principally in the Wasatch, Fort Union, Lance and Mesaverde formations. Traps are primarily stratigraphic traps caused by facies changes. Typical are alluvial sandstones localized in channel bodies of limited extent. Seals are provided by associated fine grained rocks. Source rocks are primarily associated humic-rich rocks, with some contribution from underlying Cretaceous rocks. This play has seen discovery of a few small accumulations.

Province 35. Wind River Basin

Play 3501 Basin Margin Subthrust

Laramide basin-margin thrusting has trapped oil and gas in upturned, overturned, folded, and faulted Phanerozoic strata below the overthrust wedge. Reservoir formations can be any age or lithotype with porosity, often enhanced by fracturing; principal reservoirs are Tensleep, Phosphoria, and Frontier formations. Hydrocarbons were generated from organic-rich strata of the Permian (Phosphoria Fm.), Cretaceous (Mowry, Frontier, Mesaverde, Meeteetse), and Tertiary (Fort Union Formation).

Play 3502 Basin Margin Anticline

Oil and gas is trapped in anticlines and domes, in many cases faulted, and in faulted fold noses that formed during the Laramide orogeny. Reservoirs occur in formations of Mississippian through Cretaceous age, with primary production from the Madison, Tensleep, and Phosphoria formations, often occurring in fields as multiple pay zones. Sandstone is the dominant reservoir lithotype but substantial hydrocarbons have also been produced from carbonates of the Madison and Phosphoria formations. Hydrocarbons are derived principally from two distinct geochemical source rock classes, i.e. Permian (Phosphoria Fm.) and Cretaceous (Mowry, Frontier, Mesaverde, Meeteetse).

Play 3503 Deep Basin Structure

This is primarily a gas play, although there is some oil production on the Madden structure from Paleocene Lower Fort Union and Upper Cretaceous Lance Formations at depths shallower than 14,000 ft. Traps are anticlinal, domal, and fold nose structures within the deep axial portion of the basin (to 23,000+ ft). Reservoirs range in age from Mississippian to Eocene and include clastic and carbonate rocks, and may be overpressured. Porosity and permeability, reduced through

compaction and cementation due to deep burial, may be enhanced by fracturing. Indigenous source rocks occur in the Phosphoria, Mowry, Frontier, Mesaverde, Meeteetse, Fort Union (including Waltman Shale Member), Wind River, and Indian Meadows formations.

Play 3504 Muddy Sandstone

This play comprises stratigraphic entrapment of oil and gas resulting from updip pinchouts of discontinuous sandstone units of the Cretaceous Muddy Sandstone into impermeable marine shale. In the deeper parts of the basin it may be principally a gas play. Principal source rocks are black shales of the overlying Mowry Shale and underlying Thermopolis Shale which have been buried throughout the play area to a depth sufficient to generate hydrocarbons.

Play 3505 Tertiary-Upper Cretaceous Basin Center Gas

Gas trapped in a major basin center accumulation in deep parts of the basin in Paleocene and uppermost Cretaceous sandstone reservoirs. Principal formations are Fort Union, Lance and Mesaverde. The play is characterized by a regional accumulation of gas resulting from low reservoir permeability and overpressuring due to active gas generation. Reservoirs are sandstones. Older Cretaceous rocks, which may also be geopressed, are not considered because of generally thin reservoir development and limited reservoir volumes. Sandstones, particularly localized channel bodies of limited extent, provide internal compartmentalization. Low permeability reservoirs and associated fine grained rocks furnish seals. Source rocks are humic-rich rocks and coals. This play is speculative and has seen virtually no meaningful exploration.

Play 3506 Phosphoria

This play characterizes high-sulfur oil stratigraphically trapped in the Ervay Member of the Phosphoria Formation along a generally north-south trending zone of facies change from carbonates on the west to red shale and evaporites of the Goose Egg Formation to the east. Reservoir rocks of the Ervay are porous and permeable tidally-influenced carbonates, productive to a depth not in excess of about 11,000 ft, sealed updip by tight fine-grained intertidal and supratidal carbonates. Oil was generated from organic-rich source rocks of the Phosphoria Formation.

Play 3507 Sub-Absaroka

Oil occurs beneath Eocene volcanic rocks, trapped in Laramide anticlines and domes, in many cases faulted and eroded prior to being covered by the volcanics. Productive formations are primarily

Paleozoic sandstones and carbonates, with oil locally sourced from mid-Cretaceous and older strata such as the Mowry and Phosphoria formations.

Play 3508 Coalbed Methane

This play encompasses the occurrence of gas in coals of Upper Cretaceous and Paleocene age. These coals have locally been mined. The play is generally limited to areas of Fort Union, Lance, Meeteetse, and upper Mesaverde formations at relatively shallow depths. Although occasional thin coals are found in other Cretaceous and Tertiary formations, they are not considered of sufficient quantity to include in the play.

Play 3509 Bighorn Wedge-Edge Pinchout

This hypothetical play encompasses hydrocarbon occurrence in the wedge-edge or beveled-edge pinchouts of the Ordovician Bighorn Dolomite which abut against the base of the Madison Limestone, providing potential traps. There are no known hydrocarbon occurrences and source rocks are not known.

Play 3510 Flathead-Lander And Equivalent Sandstone

This hypothetical play includes hydrocarbon trapped in stratigraphic pinchouts of the Cambrian Flathead and Ordovician Lander Sandstones.

Play 3511 Madison Limestone

This hypothetical play encompasses oil entrapment within or at the top of the Mississippian Madison Limestone caused by porosity variation and topography related to karst development.

Play 3512 Darwin-Amsden Sandstone

This hypothetical play consists of stratigraphic entrapment of oil in discontinuous sandstones of the Pennsylvanian Darwin and Amsden formations. Although there is no known occurrence of oil in such traps, these formations are productive in structural settings.

Play 3513 Triassic And Jurassic Stratigraphic Traps

This play encompasses stratigraphic traps in the Crow Mountain Sandstone and equivalent(?) Jelm Formation of the Chugwater Group, Sundance Formation, and Morrison Formation. Also, wedge-edge pinchouts and truncations of the Nugget Sandstone in the eastern and northern Wind River basin.

Play 3515 Tertiary-Upper Cretaceous Stratigraphic

Petroleum trapped in stratigraphic and combination traps in Eocene, Paleocene, and uppermost Cretaceous sandstone reservoirs, principally in the Wasatch, Fort Union, Lance and Mesaverde formations. Traps are primarily stratigraphic traps caused by facies changes. Typical are alluvial sandstones localized in channel bodies of limited extent. Stratigraphic traps in strandline, deltaic and fan deposits of the lacustrine Waltman Shale sequence (Paleocene) are also objectives. Traps are generally small. Seals are provided by associated fine grained rocks. Source rocks are primarily associated humic-rich rocks, with some contribution from underlying Cretaceous rocks, and local oil source from lacustrine Paleocene Waltman Shale. This play has seen exploration for many years, with discovery of a number of small accumulations.

Province 36. Wyoming Thrust Belt

Play 3601 Moxa Arch Extension

This structural play is characterized by probable CO₂-rich gas accumulations in Paleozoic carbonate reservoirs in footwall anticlinal traps on the axis of the arch where it extends into the province.

Play 3602 Crawford-Meade Thrust

This structural play is characterized by (1) probable hydrocarbon accumulations in footwall structural or truncation traps in Cretaceous clastic reservoirs sourced by interbedded same-age organic-rich shale, and (2) gas accumulations sourced by Paleozoic shale in tightly folded anticlines in hanging-wall traps in Paleozoic and Mesozoic reservoirs in Crawford thrust.

Play 3603 Northern Thrusts

This structural play is characterized by a range of possible trapping conditions, but mainly hanging wall anticlines, in Paleozoic carbonate reservoirs juxtaposed against Cretaceous source rocks in the footwall of three thrust systems.

Play 3604 Absaroka Thrust Gas

This structural play is characterized by gas and condensate accumulations in carbonate and sandstone reservoirs mainly in hanging wall anticlines sourced by footwall Cretaceous shale along three subparallel lines of folding on the Absaroka thrust plate.

Play 3605 Absaroka Thrust Oil

This structural play is defined by mainly oil and gas fields along an easterly line of hanging wall folds on the Absaroka thrust plate in Mesozoic clastic and carbonate reservoirs, and sourced by footwall Cretaceous shale.

Play 3606 Hogsback Thrust

This structural play is defined by probable hydrocarbon accumulations in carbonate and clastic reservoirs in highly imbricated fault traps on the hanging wall of the Hogsback thrust.

Play 3607 Cretaceous Stratigraphic

This Stratigraphic play is characterized by probable oil/associated gas accumulations in traps resulting from reservoir sandstone facies pinchout updip (eastward) into source shale facies of Cretaceous age on west-dipping, trailing edge of Hogsback thrust.

Province 37. Southwestern Wyoming

Play 3701 Rock Springs

Structural play includes the greater Rock Springs uplift. and the western part of the Wamsutter arch. Although this is principally a structural play, there are some stratigraphic trap possibilities, like the Almond in the Patrick Draw Field. Cambrian through Tertiary reservoirs are included in the play.

Play 3702 Cherokee

Essentially a structural play located along the Wyoming - Colorado State line. Cambrian through Tertiary reservoirs are included.

Play 3703 Axial

Principally a structural play with minor stratigraphic component. Encompasses all the Axial arch area between the Piceance and Sand Wash basins. Cambrian through Tertiary reservoirs are included.

Play 3704 Moxa Arch-LaBarge

Principally a structural play with some significant stratigraphic aspects, particularly in the Frontier and Dakota. Play includes Labarge and Moxa arch. Cambrian through Tertiary reservoirs.

Play 3705 Basin Margin Anticline

Structural play paralleling the thrust margins of the Greater Green River basin. Cambrian through Tertiary reservoirs, although part of

the play area overlaps Cretaceous reservoirs in one of the tight gas plays.

Play 3706 Subthrust

Structural and stratigraphic play located along the overridden thrust margins of basins. Cambrian through Tertiary reservoirs.

Play 3707 Platform

Primarily a structural play encompassing most of the area east of the Washakie and Great Divide basins. All existing fields are in structural traps. Cambrian through Tertiary reservoirs are included.

Play 3708 Jackson Hole

Structural play north of Gros Ventre Mtns. and south of Absaroka volcanics.

Cambrian through Tertiary reservoirs.

Play 3709 Deep Basin

Structural and stratigraphic play located in deeper parts (generally deeper than 15,000 ft) of Greater Green and Hanna Basins. Cambrian through Jurassic reservoirs.

Play 3710 Tight Gas

Includes Cretaceous and Tertiary reservoirs in the deeper parts of the Greater Green and Hanna basins. The play has been subdivided into five stratigraphic intervals.

Play 3711 Coalbed methane

There will be at least one coalbed methane play in Cretaceous and Tertiary coal-bearing rocks.

Play 3713 Absaroka

Structural play encompassing area underlain by Absaroka volcanics. Cambrian through Tertiary reservoirs.

Province 38. Park Basins

Play 3801 Cretaceous and Upper Jurassic Structural

In North Park the Mowry-sourced oil has migrated updip from the deeper parts of the basin through extensive fracture systems to be trapped primarily in northwest-southeast trending late Laramide structures (faulted anticlines). The play has oil and gas production from stacked reservoirs of the Jurassic Morrison, and the Cretaceous Dakota, Lakota, Muddy, Frontier, Niobrara, and Pierre Formations.

The geologic history and setting of Middle Park is similar to that of North Park but the maturity and TOC of the source rocks was not sufficient to expel commercial quantities of oil or gas. There are shows of probable Benton and Niobrara sourced oil and gas in Pierre, Codell and Dakota reservoirs in South Park on similar structures but no commercial production has been established

Play 3802 Subthrust

Rocks of the Independence Mountain Thrust (North Park) are thrust up to 12 miles over the Paleocene and Eocene Coalmont Formation. On the east side of the Blue River Valley the low angle Williams Mountain Thrust is thrust up over the Pierre Shale. The Vasquez thrust and Elkhorn thrust are similar geologically but are relatively small. The recently drilled Hunt 1-17 Tarryall penetrated the Elkhorn thrust and reached a total depth in the Pierre Formation at over 12,500 feet. The Pierre Shale is marginally to very mature and has produced some gas shows but are typically lean in TOC. In each case the rocks in the subthrusts are known to produce in adjacent provinces. Conceptual.

Play 3803 Fractured Niobrara Formation

A fractured Niobrara horizontal drilling play, while not presently producing in the Park basins, is a successful play in the Denver basin and along the easternmost edge of the Sandwash basin. Production is self-sourced, from open fracture networks in Stratigraphic traps. The Niobrara production in the North Park basin is from the same structures as play 3801. The oil appears to be genetically similar to that of the Mowry. Conceptual.

Play 3804 Coalbed Methane

There is a history of coal production in both North and South Park. In North Park probable sources are the Coalmont formation, and thin coal beds in the more deeply buried Cretaceous rocks. In South Park, coal beds are found in Paleozoic and Mesozoic rocks. Between 1885 and 1893 gas was reported from a coal mine operating near Como, probably the King mine which produced from a Laramie/Fox Hills coal seam. Coalbed methane is probably a very limited resource in the Park basins. Conceptual.

Province 39. Denver Basin

Play 3901 Sandstones of the Pierre Shale

Oil and gas are stratigraphically trapped in marine sandstones of the Cretaceous Pierre Shale (Sussex, Shannon equivalent of Terry,

Hygiene, and Rocky Ridge Sandstone Members). Oil and associated gas are produced from elongate shelf sandstones of the Terry and Hygiene Members (informally called the Sussex and Shannon Sandstones). The Spindle oil field is the largest producer from this play. Production from this play is located in the deepest part of the Denver Basin near Denver at depths of about 4,000 to 5,000 ft.

Play 3902 Fractured Shale

Oil is produced from relatively impermeable shales of the Pierre Shale and shales and limestone of the Niobrara Limestone. The Florence oil field (Pierre) of the Canon City embayment and the Silo oil field (Niobrara) of the deep Denver Basin in Colorado are two of the primary fields. Oil is produced from open fracture networks; trapping mechanisms are stratigraphic by lateral decrease in fracture density; seals are overlying unfractured shales.

Play 3903 Niobrara Limestone Gas

Gas of probable biogenic origin is produced from shallow chalk and shale reservoirs of the Niobrara Limestone. Productive depths are less than 4,000 ft from stratigraphically-trapped gas in fine-grained, low-permeability, high-porosity, organic-rich clastics. This play is located on the shallow eastern flank of the basin; most production has ranged from 800 to 2,800 ft depth. The Beecher Island field in Yuma County, CO is the best known field of this play.

Play 3904 Codell Sandstone

Oil and gas is stratigraphically trapped in marine shelf sandstones of the Codell Sandstone (Wall Creek/Turner equivalents). Reservoir sandstones have low porosity and permeability and are classified as tight gas sands. This play is located in the deepest part of the basin north of Denver. Most production is from the Wattenberg field. The earliest production was from fractured sandstones of the Boulder field. Productive depths are about 4,000 to 8,000 ft. Thermal maturity data from underlying Mowry and Graneros Shales suggests levels of 0.8% Ro and greater in the play area.

Play 3905 Dakota Group (Combined J and D Sandstones)

Included in this play are stratigraphically-trapped oil and minor gas from the J sandstone of the Muddy Sandstone, Dakota Group, and the D sandstone, both Lower Cretaceous in age. Oil and gas are trapped by overlying marine mudstones and by lateral change in facies. Primary productive facies are fine to medium-grained distributary channel and delta-front sandstones. More than 90 percent of the more than 800 million barrels of oil (MMBO) and 1.2 trillion cubic feet of gas (TCFG)

that have been produced from the basin are from this play. Adena is the largest oil field in the basin with J sandstone production and reserves of about 63 MMBO. Depths of production are about 3,000 to more than 8,000 ft. The play is located in the central and northern parts of the basin, covering approximately half of the area of the basin.

Play 3906 J Sandstone Deep Gas

Gas is produced from this play from combination stratigraphic/structural/ diagenetically trapped reservoirs of the J sandstone in the deep basin of Colorado and possibly Wyoming. Wattenberg field, in Weld County, CO, is the largest field with recoverable reserves of 1.3 (Nehring) to as much as 3 TCF of gas. Gas is produced from nearshore marine, and, to a lesser extent, distributary channel sandstones of the J sandstone. Reservoirs are low porosity and permeability due to burial depth and diagenesis, and to depositional environment. Reservoirs are underpressured and produce from about 7,200 to 8,500 ft. Elevated mean random vitrinite reflectance values of 1.1 to 1.75 percent in the area of the Wattenberg field and carbon stable isotope composition of the gas, suggests a primarily thermogenic origin for the gas with some contribution from type III kerogen. Source rocks are bounding shales of the Mowry, Graneros, and, to a lesser extent, the Skull Creek Shale.

There is no deep gas production and only very limited exploration in the basin deep of Wyoming. However, lower levels of thermal maturity of J sandstone source rocks here suggests only limited potential for gas in Wyoming.

Play 3907 Lyons Sandstone

Oil and minor gas was produced the Permian Lyons Formation, from small anticlines proximal to the western margin of the Basin, early in the history of exploration in the basin. These traps are structural and the play is located along the western margin of the basin. Traps were formed during the Laramide orogeny starting about 65 MA; migration of oil into the reservoirs post-dates this time. Reservoir rocks are eolian, fluvial, and marine sandstones. Current depths of production are about 3,000 to 10,000 ft. The largest fields are Black Hollow and Pierce, in Weld County, Colorado, which have each produced more than 10 MMBO.

Play 3908 Wolfcamp

Oil is produced from mainly carbonates of the Permian Wolfcamp in the northeastern Colorado and the Nebraska panhandle; some oil is also produced from the Wykert sand member of the Wolfcamp.

Subsurface mapping, core, and thermal maturity studies indicate potential for significant discoveries. Postulated oil traps are updip pinch-out of the porous dolomite to fine-grained clastics, and minor structures. Reservoir seals are overlying evaporites and mudstones. Producing fields include Kleinholz and Anna in Nebraska and Marks Butte and Marks Butte North in Wyoming, also, there are some shows of oil in Laramie County, Wyoming. Prospective depths of production are about 4,000 to 10,000 ft.

Play 3909 Pennsylvanian

Oil is produced from Pennsylvanian age sandstone, limestone, and dolomite in the Nebraska panhandle and far eastern flank of the basin. Prospective depths of production are about 3,000 to 10,000 ft from cyclical sandstone-limestone-dolomite sequences of the Des Moines, Missouri, and Virgil. The Swearingen field in Nebraska produces oil and gas from a depth of 8,190 ft in the Missouri and 7,900 ft in the Permian Admire.

Play 3910 Subthrust Structural

This speculative play includes production of oil and gas from Mesozoic and/or Paleozoic sediments buried under thrust faults that border the western margin of the Denver Basin. Proposed reservoir units include the J sandstone of the Dakota Group, and, to a lesser extent, the Pennsylvanian Fountain Formation, and the Permian Lyons Sandstone. Current exploration is confined to seismic data. Potential trapping mechanisms are structural and stratigraphic. Hydrocarbons could be trapped under the thrust sheet of Precambrian rocks, they could be present in stratigraphically-trapped reservoirs, or could occur in fractured rocks. Times of trap formation are Laramide to possibly Eocene time. Because of the depths of occurrence (6,000 to more than 14,000 ft) potential source rocks would be mature to overmature. Some production could be shallower, as it is based partly on thickness of overlying Precambrian strata.

Province 40. Las Animas Arch

Play 4001 Upper Pennsylvanian [Virgilian]

Oil play in the upper Pennsylvanian Virgilian rocks of northeastern Las Animas Arch, Cheyenne County, Colorado. Traps are predominantly structural [anticlinal] and occur in shelf limestones.

Play 4002 Pennsylvanian (Missourian)

South central Las Animas Arch Pennsylvanian [Missourian] structural and stratigraphic oil and gas play. Reservoirs occur primarily in shelf limestones of the Lansing and Kansas City Groups.

Play 4003 Pennsylvanian (Desmoinesian)

Northwest Las Animas Arch Pennsylvanian [Desmoinesian] structural and stratigraphic oil play. Reservoirs occur primarily in shelf limestones of the Marmaton Group.

Play 4004 Lower Pennsylvanian (Morrowan)

Las Animas Arch Lower Pennsylvanian [Morrowan] stratigraphic [primarily facies changes] gas and oil play. Reservoirs occur primarily in valley-filling fluvial sandstones.

Play 4005 Mississippian (Meramecian/Osagean)

Central Las Animas Arch Mississippian [Meramecian/Osagean] structural and stratigraphic [anticlines, facies changes, faulted anticlines] oil play. Reservoirs occur primarily in shelf carbonates.

Province 41. Raton Basin - Sierra Grande Uplift

Play 4101 Upper Cretaceous-Lower Tertiary Gas

This is a conceptual gas play in the Trinidad, Vermejo, and Raton Formations in the central portion of the Raton basin, southern Colorado-northeastern New Mexico. The play includes conventional and probably unconventional reservoirs in clastic rocks in the basin; traps are primarily stratigraphic.