Covenant Field: A major oil discovery in the Sevier thrust belt of central Utah

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The overthrust belt of western North America extends from British Columbia to southern Nevada. Large anticlines lie on thrust sheets along the length of this overthrust trend. Many oil and gas fields have been discovered on these structures in Canada, but significant hydrocarbon production in the United States has been primarily limited to a productive salient in southwestern Wyoming and northeastern Utah (Figure 1). On 23 December 2003, Wolverine Gas and Oil-Kings Meadow Ranches well 17-1 drilled into a 487-ft oil column in the Navajo Sandstone in Sevier County, Utah. This new significant oil reservoir is 146 miles southwest of the nearest thrust belt production at Pineview Field in Summit County, Utah. The discovery of what we call Covenant Field is not only a major discovery for Wolverine Gas and Oil but could open up a new Mississippian-sourced oil and gas province in central Utah.

Regional geologic setting. Covenant Field is on the leading edge of the Sevier thrust belt. In central Utah, the leading-edge thrust is proximal to and generally follows the strike of a NNE–SSW structural “hingeline” that has influenced sedimentation and stratigraphy since the Paleozoic. This hingeline is defined by the trace of the major Ephraim Fault and marks the eastern edge of the Sevier thrust belt province. The stratigraphic column for central Utah (Figure 2) has a fairly complete section of strata from Cambrian to Quaternary. The reservoir in Covenant Field is the Navajo Sandstone which reaches a thickness of over 1250 ft. The Navajo is an excellent reservoir rock composed of aeolian dune sets with good porosity and permeability.

The oil in the field has been molecularly fingerprinted to a robust, TOC-rich Mississippian-aged source rock system in eastern Nevada and western Utah. The seal rock is the Arapien Formation—shale, gypsum, salt, and limestone and regionally less than 3000 ft thick. The Arapien is a ductile formation that flows plastically when deformed. At Covenant Field, the Arapien has been tectonically thickened to as much as 9000 ft.

Early exploration efforts. The bedrock geology in Sevier County was first mapped by Dutton in 1890. He observed a large surface anticlinorium 30 miles in length and 4 miles wide in which the older Jurassic Arapien Formation was exposed and bounded by younger Cretaceous and Tertiary strata. Figure 3 shows the bedrock geology of Sevier County with the 67 671 acre Wolverine Federal Unit outlined in red. Gray within the federal unit polygon indicates the outcropping Arapien Formation.

Well control in central Utah is extremely sparse. Prior to drilling discovery well 17-1, only two wells had penetrated the Navajo Formation within the Wolverine Federal Unit. The first, SOCAL-Sigurd 1 drilled in 1957, encountered a wet Navajo reservoir at a measured depth of 8997 (-3491 SS) ft. An examination of the drilling prognosis constructed by SOCAL indicates that they had expected to encounter the Navajo Formation at a depth of 3000 ft and that this planned 9000-ft test would drill through the entire Paleozoic section.

They were surprised to find the Navajo Formation at a much greater depth with an overlaying Arapien section tectonically thickened by a factor of 3. In 1981, encouraged by the discovery of hydrocarbons at Pineview Field and with additional but still limited seismic and gravity surveys, a second Navajo test, the Chevron-Salina 1 well, was drilled. This well, 1 mile northeast of Socal-Sigurd 1, was drilled to a depth of 17 423 ft and encountered the Navajo Sandstone twice—at true vertical depths of 8974 (-2950 SS) and 15 401 (-9377 SS).
ft in both a hanging wall and footwall position along the plunging nose of a large fault-bend fold. Although no commercial shows of hydrocarbons were encountered, the fault-bend fold geometry established by the well proved that the Arapien outcrop was caused by thrust tectonics as opposed to Arapien salt diapirism.

**Wolverine prospect generation.** Chevron acquired additional 2D seismic after drilling Salina 1 but ultimately put the area up for sale. Doug Strickland, exploration manager for Wolverine, was familiar with the geology of the area from his dissertation study and past exploration work as a Chevron geologist. In April 2000, Wolverine bought Chevron’s lease position and obtained a geophysical grid to begin mapping the thrust sheets to develop a prospect.

It was evident from the geophysical mapping that there were several large fault bend fold structures on the lease block. To establish a prospect, Wolverine had to be able to demonstrate that a viable source existed for charging these structures with hydrocarbons after they were in place. Detailed regional, restored, balanced cross-sections were constructed using the bedrock geology, seismic, and well control to determine when each thrust sheet within the Sevier thrust belt moved and structures were emplaced. In 2001, a geochemical study was initiated by Wolverine to find a hydrocarbon source for charging the structures. This study included more than 1000 surface and subsurface rock and liquid samples along with 1D Lopatin TTI burial models from key wells in which source rocks were present. It was determined from the geochemical study that the Mississippian could have provided a gas charge to source the structures within parts of the Sevier thrust belt.

**Partner solicitation.** Having a viable prospect mapped with apparent trap, reservoir, seal, and source in place, Wolverine Gas and Oil began to look for industry partners to defray costs and reduce risk. The process of finding partners was long. The “Wolverine Salina Prospect” was shown at two North American Prospect Expos, the Calgary Prospect Exchange, and presented to 65 major oil companies and independent oil and gas producers over a 22-month period in 2002 and 2003. Seventy-five percent working interest in the prospect was finally sold at cost to 14 partners (independent producers and business friends). The largest industry partner bought a 10% working interest and the smallest industry partner a 1.25% working interest.

Wolverine could see that it would take a number of wells and many months to develop the prospect whether the first well was successful or not. So during the time of soliciting partners, Wolverine formed a Federal Unit to hold the leases which were on federal (50%), state (34%), and private (16%) lands. The creation of the Federal Unit would allow Wolverine to hold all the leases within the 104 square mile Federal unit for 10 years by drilling three exploratory tests on three different structures.

**First well a hit!** The first test on the first structure was a success. The WGO-KMR 17-1 discovery well encountered the Navajo Sandstone at a measured depth of 5846 (-94 SS) ft. This was 2856 ft high to the Chevron-Salina 1 well located 3.5 miles down plunge to the north and east. When the Navajo was penetrated by the discovery well (Figure 4), Roger Charbonneau, the mud logger, called Sid Jansma Jr. (owner, president, and CEO of Wolverine Gas and Oil) to report oil shows with florescence. As geologists, we were excited but also a little unsure of what we had because we were carrying only 60 unit shows with a 10.6 lb mud weight, and we had no nearby analogs for comparison. We did not know for sure if we were in an oil-pay section. After drilling 487 ft of oil shows, the mud logger called to say we were out of the shows and into the water but still in the Navajo...
sandstone. At this time we suspected that we had hit an oil-water contact. Well logs were run, and the 487-ft Navajo oil-pay section was confirmed. After logging, we continued to drill while putting 22 landmen in the field to lease up the play while it was still a secret from the rest of the industry.

**Complex structure.** The Covenant Field structure was initially mapped using a coarse grid of 2D seismic data acquired by Chevron and reprocessed by Wolverine. Early seismic imaging in the Salina thrust belt area had been historically difficult due to steeply dipping beds, irregular topography, low fold, short far-trace receiver offsets, short line lengths, and poor geophone coupling and signal transmission in the soft, outcropping Arapien Shale and hard surface volcanics. The overall geometry of the fault-bend fold within the triangle zone of the leading-edge thrust was roughly imaged prior to the drilling of the WGO-KMR 17-1 well, but exact reflection/formation identification on the hanging wall was difficult because of the poor signal-to-noise ratio in the seismic, along with the lack of well control.

Wolverine had three surprises in drilling the discovery well. First, the Navajo Sandstone came in 1600 ft above the drilling prognosis. Second, the hydrocarbon pay in the structure was oil and not gas as predicted by the source modeling. Third, a second Navajo sheet was encountered at a measured depth of 8146 (-2389 SS) ft in duplex structure, not a simple fault bend fold as seen in the Chevron-Salina well 1.

The geometry of the Covenant Field structure is shown on seismic line WGO-04-002-SLN (Figure 5) which has a NW–SE orientation and is perpendicular to the axis of the structure. The section is a poststack migration plotted with a 1:1 vertical to horizontal exaggeration. The footwall and the hanging wall are separated by the Salina thrust (shown in red). The Navajo reflection is in gold. The location of well 17-1 is posted on the top of the section. The two Navajo sheets encountered by the well are shown as a lower fore-thrust and an upper backthrust. The presence and geometry of the upper backthrust sheet has been confirmed by additional seismic and well control. The top of the Arapien Formation is the magenta horizon. The Arapien outcrops at the surface where the well location. The Arapien is tectonically thickened and forms a classic triangle zone along the length of the structure. On the upper right of the section at 1.0 s, one can easily see an angular unconformity at the Tertiary-Cretaceous boundary. This unconformity dates the last thrust movement on this structure at approximately 65 Ma.

To date, the limits of the upper Navajo backthrust sheet in Covenant Field have been tested by 10 producing wells drilled near the crest of the structure and a dry hole drilled off structure. These wells were drilled directionally from two surface pads to minimize the environmental footprint. All producing wells make oil and some produce oil and water. Production data strongly suggest that Covenant Field has an active water drive. A water disposal well was drilled at the Wolverine Central Production Facility 4000 ft northwest of the producing wells. The water disposal well did not encounter the upper backthrust Navajo sheet but did encounter the lower forethrust Navajo sheet at a measured depth of 8781 (-3174 SS) ft. Figure 6 shows a balanced geologic structural cross-section constructed by Dan Schelling over Covenant Field. The cross-section incorporates the subsurface formation tops encountered by the wells, the seismic control, and the surface bedrock geology. The geometry of the hanging wall and footwall are shown along with the major thrust faults. Basin and range extensional faulting, that began in the Miocene and continues to the present, has

![Figure 5. Poststack migration of seismic line WGO-04-002-SLN trending NW–SE over Covenant Field.](image)

![Figure 6. A balanced geologic cross-section constructed by Dan Schelling is shown for Covenant Field. Balanced palinspastic restorations constructed from the integrated interpretation of seismic with surface and subsurface geologic control have aided in determining the timing of thrust episodes and structural trap creation in the Sevier thrust belt of central Utah.](image)

![Figure 7. Back-thrust upper Navajo sheet structure map over Covenant Field. Contour interval = 200 ft. The green line shows the location of seismic line WGO-04-002-SLN shown in Figure 5.](image)
modified the sides of the triangle zone. Relaxation of faults, parallel to the back limb of the fault bend fold, have created accommodation space for the deposition of Sevier Formation in the Salina Valley to the west of the structure. These Neogene basins are often found on the back limbs of large thrust structures in central Utah within the basin and range province. A subsea structure map for the upper back-thrust Navajo sheet is shown in Figure 7. The map contour interval is 200 ft. The green line crossing the field with a NW–SE orientation shows the location of the seismic line in Figure 5. The 10 producing oil symbols (in green) show the bottom-hole location of the Wolverine wells drilled near the crest of the structure.

Complex play. Covenant Field is a significant hydrocarbon accumulation 146 miles away from analog production. The field lies along the Sevier thrust belt trend where numerous structure trap targets exist. Molecular fingerprinting has linked the hydrocarbons in the field to long-distance migration from robust Mississippian source rocks in eastern Nevada and western Utah. A Lopatin TTI model from the Shell Sunset Canyon well, the closest well with significant source rock west of Covenant Field, shows that the source rock entered the oil generation window 140 Ma. As mentioned previously, the last thrust movement at Covenant Field developed at 65 Ma, 75 million years after the earliest oil generation. The oil is a light 39.4 API gravity with a very low gas-to-oil ratio. The gas-depleted oil is believed to be evidence of remigration from a paleo accumulation. Ongoing diagenetic study indicates that illite precipitation in the Navajo sandstone at Covenant Field stopped 88 Ma due to either oil emplacement or structural inversion or both. In any case, the data indicate that a paleo accumulation was present at the location of the field prior to the last episode of thrusting. Future successful oil and gas exploration in central Utah will continue to depend on the understanding and integration of present-day traps with hydrocarbon migration systems and paleo accumulation trap locations.

Field status. The WGO-KMR 17-1 discovery well was completed and put on production in May 2004. The well flowed more than 300 barrels per day from a 10-ft perforated interval at the base of the Navajo pay section. A submersible pump was placed in the well, and it has produced 700–800 barrels per day since that time. All 10 producing wells shown in Figure 7 were drilled and completed by April 2006. As of September 2006, Covenant Field had produced 2.6 million barrels of oil with daily production around 7000 barrels. Wolverine plans to drill a deep test to the Paleozoic in the field along with 1–2 additional Navajo tests in the second and third quarters of 2007 during the open big-game drilling window. Wolverine has acquired more than 450 000 acres in this area and continues to be the major player in the exploration of the central Utah Sevier thrust belt play.

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