A New Look Finds a Giant

Innovative thinking and a new play concept finds a giant gas field on a lease block that had been explored for 50 years and drilled 11 times.

Editor's note: Before arriving in Beijing, China, I had contacted Dr. Ma and his assistant, Mr. Jin, by email. I had some apprehensions going for the first time to this large country. Upon meeting the assistant and his driver at the airport, the butterflies were quickly erased. I was given dignitary treatment and unbelievable access. This article chronicles the discovery of a gas field that has changed the face of exploration in China and has important implications for exploration in other maturely explored basins.

With a Puguang gas well drilling in the background, entire mountains have been leveled to make room for the largest gas plant to be built in Asia. A 1,702 km long east-west pipeline is also under construction to bring gas to the major east coast cities such as Shanghai. Photo: Tom Smith

Dr. Yongsheng Ma's expertise in carbonate systems helped unravel the paleogeography in the northeastern Sichuan Basin. Correctly identifying the different marine platform carbonate facies and prospective reservoirs led to this important gas discovery. Photo: Yongsheng Ma

Thomas Smith, Associate Editor

The 1,100 km² lease block is located in the northeastern Sichuan Basin. Triassic and Permian carbonate reservoirs on structural highs had been targeted for drilling for close to 50 years. However, it was not until Dr. Yongsheng Ma, President of Exploration for SINOPEC, looked at the previous studies and decided that the data had not been honored. More work needed to be done and he assembled a team to do just that. What followed was a major discovery that changed the exploration scope in the basin and the entire country. It has prompted a massive construction effort to deliver gas to the east and provides the rest of the world with an analog for exploration in other complex carbonate reservoirs.

Slow Progress

The late Mesozoic to Cenozoic foreland Sichuan Basin is situated in the western part of the Yangtze craton in south central China. Covering over 180,000 km², the basin comprises a 6,000 to 12,000 m thick Late Precambrian to Cenozoic sedimentary succession. It has been explored since the early 1950's which resulted in several large gas fields and some small oil fields in the south and central portion of the basin.

"The eastern portion of the basin where the Puguang gas field was discovered was slow to be explored because of the high relief, rough terrain, and complex structure," says Dr. Ma. "A large gas field (Wubaiti) was discovered in 1989, primarily as the result of the more advanced seismic techniques that came available in the early 1980's."

The Puguang structure was first drilled by Star Oil Company, the Chuanyue 83 well, in 1986. The well encountered gas in fractured limestone, confirming the gas potential of the area. However, no major fields were found after drilling an additional 11 wells on the lease where the giant Puguang gas field was later discovered.

Looking in the Wrong Place

Meanwhile, several large discoveries were made in the northeastern part of the basin. "These discoveries all had one thing in common when I looked at the data," says Dr. Ma. "Producing zones were in Upper Permian to Lower Triassic reef and shoal dolomites. This suggested that good reservoirs can ▶

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Discovered in 2003, the Puguang gas field is located in the northeastern Sichuan Basin of southwest China.

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The fringing reefs and oolitic shoals of the Bahamas provide a reservoir analog for the Puguang field carbonate play.

form in certain depositional facies and gas deposits may have more of a stratigraphic component than a structural one."

As the chief geologist for the Southern China Exploration and Production Company (a branch of SINOPEC), Dr. Ma decided to take over the lease block that everyone told him "to stay away from". His extensive education in carbonate depositional systems sold him on the idea that the previous studies were inadequate.

"I assembled a team to take another look at the data here," says Dr. Ma. "I felt the previous studies did not honor the available data on the depositional systems. We gathered everything we could find in this part of the basin and set out to map the depositional facies."

The hard work paid off when SINOPEC drilled the Puguang 1 and completed the well in porous dolomite. This well encountered the same horizon on the same structure 1,300 m deeper than the Chuanyue 83 wildcat. Development wells have now confirmed the discovery as a giant gas field with reserves exceeding 380 Tm³ with a gas column of 830 m.

Reservoir Rocks

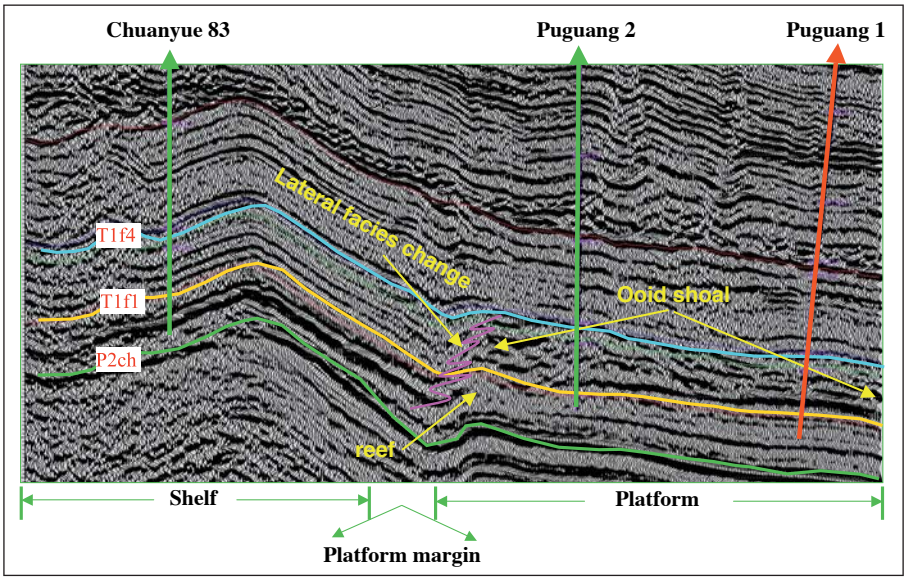
"Previous studies had modeled a deep trough where we were finding evidence of shallow, even tidal flat deposition. If you look at present day Great Barrier Reef or at Andros Island in the Bahamas, you can see why it is so critical to have an accurate depositional model and geologic history for the area," says Dr. Ma.

"Analysis of the existing geologic, drilling, logging and seismic data showed favorable porosity development to be mainly in the platform-margin shoal and evaporitic platform environments. We used this data to reconstruct the paleogeography and facies distribution which allowed preliminary trap delineation," says Dr. Ma.

The distribution of the Late Permian and Early Triassic reservoirs are controlled primarily by depositional facies. This is why the reconstructions of the paleography are so important. The best reservoirs occur in oolitic dolomites deposited along the platform-margin shoal. The present day analog would be the oolitic shoals common to Andros Island in the Bahamas.

"The porosity and permeability of the oolitic facies is impressive at any depth," says Dr. Ma. "Here, we have exceeded what was believed to be the lower depth limits for porosity development in this region by over 2,000 m."

The previous porosity depth limit for the region was 3,500 m. New wells have increased that to 5,500 m. The presumed maximum burial at the Puguang reservoir is in excess of 6,000 m with a retained maximum porosity of 28%. This constituted a new burial depth record for China. These depths have been recently passed with a well encountering good reservoir quality at 7,300 m.



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The Puguang 1 discovery well was drilled 1,300 m down dip from the Chuanyue 83 well that was drilled near the crest of the anticline. The Puguang 2 confirmed the gas discovery with over 270 m of net pay in the carbonate reservoirs.

Obtaining seismic data can be difficult in this area near the Puguang gas field. Photo: Tom Smith

Porosity in the dolomitized oolites is primarily solution vugs and caverns, 80% of the bulk porosity and intercrystalline making up the remainder. Porosities can be as high as 29%, with core porosities averaging just over 8%. Permeability averages 94 md with micro-fractures that formed synchronous with the field structure, contributing to improved permeabilities.

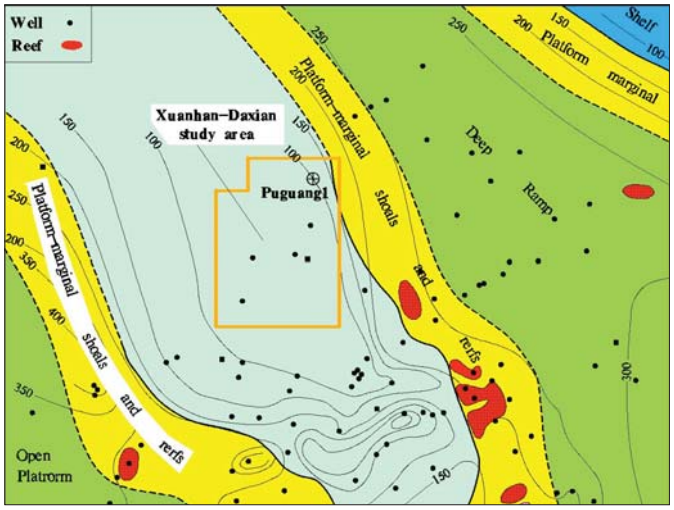
Never Give Up

"New ideas bring new discoveries," says Dr. Ma. "I never say no to new ideas and exploration. No matter how explored an area is and how much work has been done there, more work still needs to be done."

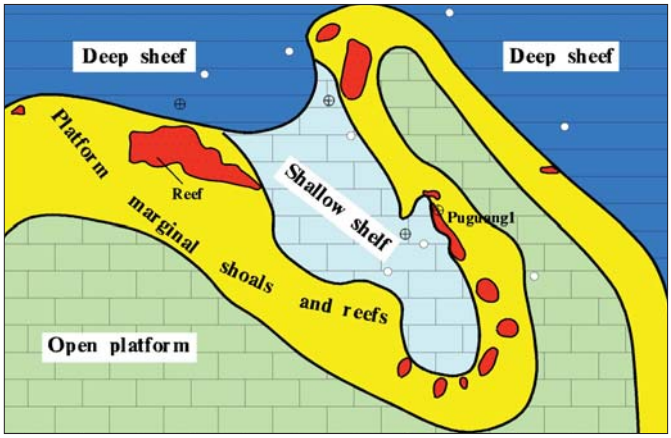
The discovery of the Puguang field is testament to his words. This small lease block had been given up as "not being prospective for hydrocarbon exploration" after 11 wells, all but one dry, had been drilled. In fact, most of the Sichuan Basin, after 50 years of exploration, had been written off by some companies. Now, with the Puguang and other recent discoveries, a huge potential remains for the basin.

"New play concepts, along with advancements in technology to evaluate the subsurface, are critical for exploration of any area. We have seen substantial improvements in seismic acquisition and processing in mountainous areas. Using direct hydrocarbon indicators and seismic inversion techniques, oolitic shoal dolomites can be recognized in the subsurface. This has enabled geoscientists to predict reservoirs and do more precise geologic modeling prior to exploratory drilling."

"This discovery has broadened the scope of our exploration here in China. It can serve as a model for exploration in other maturely explored basins", Dr. Yongsheng Ma concludes.



Previous studies of the area resulted in modeling a Late Permian oceanic trough (light blue) where the Xuanhan-Daxian lease block is located and, therefore, in an unfavorable depositional setting for hydrocarbon prospecting.



The new Late Permian paleographic model (use Puguang 1 as a reference between the two models) has shallow shelf and platform shoals and reefs that were once mapped as oceanic trough. This new model was tested by the Puguang 1 well finding porous Late Permian and Early Triassic platform margin ooid carbonates. This model has now been tested across the area by the drilling of 24 new wells and a 100% success rate.

Operations

The tour included a look at the drilling operations at the Puguang field and the construction efforts the discovery has prompted to bring this gas to the eastern China markets.

The drilling supervisor provided a very complete tour of the rig drilling on location at the Puguang gas field. It had to be the cleanest and most orderly location I have ever seen. Mr. Weizuecheng was obviously proud of this and took a great deal of pride in running a tight ship. Everything was up-to-date and state of the art. He was quick to point out American made equipment being used at the well site, which was substantial.

"We work with many contractors, both Chinese and outside, to support the drilling operations," says Mr. Weizuecheng. "Contractors like Schlumberger, Baker-Hughes, Weatherford, Macobar, and many more supply the services necessary to keep drilling and to properly evaluate and complete our wells."

"This is a surprisingly difficult area to operate in. One of the real challenges of operating in the northeastern Sichuan Basin is getting rigs to the drilling locations," says Mr. Weizuecheng. "Roads are narrow, steep, crooked, and filled with people and vehicles of every size and shape. It can take weeks and sometimes months to move a rig. In the summer, it is extremely hot, humid and rainy, making operations very dangerous for the workers."

The Puguang discovery not only changed exploration targets throughout the region, but has sparked a construction boom that rivals any I have ever seen, including construction of the Trans Alaskan Pipeline.

Educated at Colorado School of Mines in Golden, Colorado, drilling supervisor Mr. Weizuecheng explains the workings of the drilling rig used to drill these deep gas wells. Much of the equipment used here was made in the U.S. Photo: Tom Smith

To get on location, drilling rigs must negotiate narrow, busy roads. Photo: Tom Smith

The building of the gas plant has displaced thousands of families leading SINOPEC to build new living quarters and provide the local communities much needed services. Photo: Tom Smith