1. Brief Introduction to the basin

1.1 Tectonic setting and basin outline

The western depression is the deeply subsided part of the Sichuan continental basin since late Triassic, with a great tight sandstone gas resources.

The basin appears a geomorphologically rhombic basin, where widely occur Mesozoic and Cenozoic red clastic rock series. Its area is about $200 \times 10^3 \text{ km}^2$. The area of western depression is $30 \times 10^3 \text{ km}^2$. 
The basin is a structural basin, founded above crystalline and metamorphic basements formed before the Jinning age, then having experienced two major geological processes of carbonate platform and continental clastic sedimentary basin, and, finally, deformed by late tectonic event, especially by Himalayan movement. The Western Depression is a Foreland Basin.

Based on the tectonic events in the surrounding mountains, the evolution of west Sichuan depression can be divided into seven stages:

1. Passive continental margin stage in Ma-antang period ($T_3m$) of Late Triassic
2. Foreland basin stage from Xiaotongzi ($T_3t$) to Xujiahe ($T_3x$) period of late Triassic
3. Foreland basin shrinkage and disappear stage in early Jurassic ($J_1$) to Suining period of late Jurassic ($J_3s$)
4. Intra-continental depression stage in Penglaizhen period ($J_3p$) of late Jurassic
5. Intra-continental basin shrinkage and disappear stage of early Cretaceous Ecocene epoch
6. Structural remnant basin stage in Oligocene epoch - Pliocene epoch
7. Foreland-like basin stage of Quaternary
Intra-continental depression stage in Penglaizhen period (J3p) of late Jurassic

Intra-continental basin shrinkage and disappear stage of early Cretaceous (K1) - Eocene epoch (E2)

Sedimentary Facies Map of Sichuan Basin in Late Cretaceous

Section of geological structure in the west Sichuan depression

1.2 Sedimental age and characteristics of reservoir, source and seal

The deposition in Sichuan basin began in Sinian and ended in Eocene. Two Sedimental stages are recognized by different sedimentary characteristics.

(1) Carbonate Platform Stage

The stage before late Triassic was dominated by marine deposition with a thickness of 3000-6000 meters. After middle Triassic, the early Indosinian movement ended the extensive carbonate deposition and formed gentle structures.

(2) Continental Basin Stage

Due to the uplifting of Longmenshan Mountain in late Triassic, Sichuan foreland basin was formed, and the continental basin evolution stage started. The thickness of continental deposits ranges from 5000 to 8000 meters. But the existing thickness at present is 2000-6000 meters due to denudation.
Rich Source Rock —basis for large-middle scale gas fields

- Rich gas source rock in the continental clastics in west Sichuan basin, being the basis of forming large-middle scale gas fields
- The main source rock is in late Triassic
- The secondary, gray mudstone in Jurassic.

Source Rocks For T₃x²

Maantang Formation (T₃m)
Xiaotangzi Formation (T₃t)
2nd member of Xujiahe Formation (T₃x²)

Characteristics of T₃X² Source Rocks

- Lithology: lacustrine-swamp black mudstone and shale, coal
- Thickness: 60-80m
- Organic matter (%): 2.51%
- Kerogen type: III
- Ro: 1.76%
- Gas-generation intensity: 2-2.5 \( \times 10^9 \text{m}^3/\text{km}^2 \)

Characteristics of T₃m & T₃t Source Rocks

- Lithology: marine mudstone and littoral plain-swamp mudstone
- Thickness: 100-500 m
- Organic matter (%): 1.11
- Kerogen type: II-III
- Ro: 1.8%
- Gas-generation intensity: 4-5 \( \times 10^9 \text{m}^3/\text{km}^2 \)

Reservoir

- 2nd member of Xujiahe formation (T₃x²), upper Triassic
**Triassic Xu² Play**

- **Seal Rock**: T₃x², T₃x³ mudstone
- **Trap Type**: fractural-porous
- **Reservoir Lithology**: fine-medium sandstone
- **Porosity & Permeability**: \( \phi = 2-8\% \ K = 0.02-0.2 \) md
- **Buried Depth**: 4530-4850 m
- **Pressure Factor (MPa/100m)**: 1.55-1.73
- **Resources in Place**: 650 \( \times 10^9 \) m³
- **Proven Reserves in Place**: 6.7 \( \times 10^9 \) m³

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**Petroleum Geology Characteristics and Exploration Maturity of the Xujiahe Formation**

- **Super-high geo-pressure**
- **Large buried depth**
- **Super-tight sandstone**
- **Low exploration maturity**

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**1.3 History of petroleum business in the basin: licensing, exploration, development, production and sales of HC.**

**Licensing:** Since 1988, we applied for licenses from the government. Now, we have got 9 licenses. All of the exploration, developments, production and sales of HC are legal.

**Exploration:** Exploration activities started in 1950's. A dozen of gas fields have been found in Western Depression. The proved and probable reserves reaches to 230 \( \times 10^9 \) m³.

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**License Blocks**

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**Proved Reserves Growth (SWPC)**
Developments, production and sales of HC:

The activities of development and production began in 1980’s. Annual gas production increased rapidly in recent years. 1.5 billion cubic meters of gas was produced in 2002. Main consumers are citizens, chemistry factories and power plants.

1.4 Petroleum companies active in the basin

Two main companies, Southwest Oil & Gas Field Company (SOGFC), PetroChina and Southwest Petroleum Company (SWPC), SINOPEC, active in the basin.

1.5 Current fiscal regime

1. Nature gas price: ¥669/1000 m³ ($81/1000 m³)
2. Sale tax: 11.5-14.5%
3. Income tax: 33%
4. Resource tax: 5-15 RMB/1000 m³

2. Challenges for the basin

2.1 Resource assessment

Since 1985, several resources assessment have been done. But the results are quite different. How to determine the expulsion & accumulation coefficient of hydrocarbon is the main factor which affects the results.

<table>
<thead>
<tr>
<th>Author</th>
<th>Time</th>
<th>Resource volume (10⁹ m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr. Wang Tingbin, etc</td>
<td>1985</td>
<td>146.0</td>
</tr>
<tr>
<td>Mr. Yan Huaiyu, etc</td>
<td>1985</td>
<td>222.0-397.0</td>
</tr>
<tr>
<td>Mr. Deng Kanglin, etc</td>
<td>1992</td>
<td>480.1-864.9</td>
</tr>
<tr>
<td>Mr. An Fengshan, etc</td>
<td>1993</td>
<td>600-1400</td>
</tr>
<tr>
<td>Mr. Li Mengke, etc</td>
<td>1994</td>
<td>600-1000</td>
</tr>
<tr>
<td>Mr. Tang Lizhang, etc</td>
<td>2002</td>
<td>1800-2500</td>
</tr>
</tbody>
</table>
2.2 Industry activity

Longmenshan thrust belt is prospective and little petroleum activity has been done there. Because the structures are very complex and traps are very difficult to be delineate.

2.3 Exploration

The mean resource volumes are about $2150 \times 10^9 m^3$. The proved and probable reserves is $230 \times 10^9 m^3$. Only 11% of the resources has been discovered. Therefore, it still has large, potential volumes that have not yet been discovered. The undiscovered resources are mainly in the deep, very tight sandstone among Xujiahe Formation.

2.4 Development

Because of tight reservoir and low gas flow rate, about one-third of the proved reserves has not been developed. Hydro-fracturing is the major method to stimulate the reservoir. But it does not work for tighter reservoirs. Natural fracture prediction is very important to develop the tight gas.

2.5 Production

SWPC has about 100 billion cubic meters of proved reserves. If the rate of production is 3%, 3.0 billion cubic meters of annual production could be expected. But now the annual production is only 1.5 billion cubic meters, half of the expected production. Apart from the reservoir stimulation technology, other production technologies are also needed, such as the technique that one well produces gas from several pay zones separately at the same time.

3. First Case Study Workshop

3.1 Agenda and resource persons attending

As you know, because of the SARS, the first workshop of China case study was postponed from May 19-24 to October 20-25. I think that the weather in October is better than that in May in Chengdu. It is cool and the scenery is more beautiful. The first workshop of China case study will be hold in next month in Chengdu. I’d like to take the chance to introduce something about the workshop.

Day1: October 20, 2003, Monday
08:30 Registration
09:00 Opening Ceremony
Address by Mr. Gunnar V. Solland, Mr. Zheng Chuncai, Mr. Yang Keming
10:00 Group photo and coffee break
11:00 Introduction of the Case Study Members
11:30 Case Study Plan and main contents for the first workshop…Mr. Wang Chuan
13:00 Brief introduction to the geology, exploration and exploration in Western Depression of Sichuan Basin …Mr. Chen Zhaoguo
15:00 Coffee break
15:30 The application of GeoX in China… Mr. Yang Dengwei
18:00 Welcome Dinner hosted by the Southwest Petroleum Company, SINOPEC. Attire: smart casual
Day 2: October 21, 2003, Tuesday
08:30 Procedures and principles of the geological risk analysis of NPD … Ms. Inger Pedersen Fjaertoft
10:00 Coffee break
10:15 Continue
12:00 Lunch
13:00 Continue
15:00 Visit the Panda Breeding Center
17:00 End of day 2

Day 3: October 22, 2003, Wednesday
08:30 Procedures and principles of the geological risk analysis of NPD (Continue) … Ms. Inger Pedersen Fjaertoft
10:00 Coffee break
10:30 The CCOP Resource Classification System … Mr. Gunnar V. Soiland
11:15 The CCOP Guidelines for Risk Assessment … Mr. Simplicio P. Caluyong
12:00 Lunch
13:00 Netmeeting on new features in GeoX 5.2 and insight on the multisegment tool (from 6AM to 9AM Oslo time)
17:00 End of day 3

Day 4: October 23, 2003, Thursday
08:00 Excursion: one day trip to visit Qincheng Mountain and Dujiangyan Irrigation Systems.

Day 5: October 24, 2003, Friday
08:30 Philippines experience in using the GeoX multisegment tool and exercise on multisegment prospect assessment … Ms. Ma. Corazon Sta. Ana
10:00 Coffee break
10:30 Continue
12:00 Lunch
13:00 Introduction to the X2 play and exercise on X2 play assessment ……….. Mr. Yang Dengwei
15:00 Coffee break
15:30 Continue
17:00 End of day 5

Day 6: October 25, 2003, Saturday
08:30 Continue the two exercises
10:00 Coffee break
10:30 Continue the two exercises
12:00 Lunch
13:00 Group presentation and discussion of the exercises…………………Mr. Simplicio P. Caluyong
15:00 Coffee break
15:30 Group discussion to the future needs of China case study ………………Mr. Gunnar V. Soiland
16:00 Summation and conclusion … Mr. Gunnar V. Soiland
17:00 End of the 1st workshop
18:30 Farewell dinner hosted by CCOP. Attire: smart casual

Resource persons:

MS. INGER PEDERSEN FJAERTOFT (NPD)
MS. MA. CORAZON STA.ANA (DOE)
### 3.2 Participants:

<table>
<thead>
<tr>
<th>Geologist</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>MR. YOUNG-JOO LEE</td>
<td>Korea</td>
</tr>
<tr>
<td>MR. HYUN-TAE KIM</td>
<td>Korea</td>
</tr>
<tr>
<td>MR. BOB YULIAN</td>
<td>Indonesia</td>
</tr>
<tr>
<td>MR. ABDULLAH SODIK</td>
<td>Indonesia</td>
</tr>
<tr>
<td>MR. DJOKO SUMALJO</td>
<td>Indonesia</td>
</tr>
<tr>
<td>MR. SASONGKO HADIPANDOYO</td>
<td>Indonesia</td>
</tr>
<tr>
<td>MR. MEN DEN</td>
<td>Cambodia</td>
</tr>
<tr>
<td>MR. HOUY VUTHA</td>
<td>Cambodia</td>
</tr>
<tr>
<td>MR. AGUS GUNTUR</td>
<td>Indonesia</td>
</tr>
<tr>
<td>MR. SILAMBI PALAMBA</td>
<td>Indonesia</td>
</tr>
<tr>
<td>MR. SIMPLICIO P. CALUYONG</td>
<td>Philippines</td>
</tr>
<tr>
<td>MR. MEN DEN</td>
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<td>Indonesia</td>
</tr>
<tr>
<td>MR. SILAMBI PALAMBA</td>
<td>Indonesia</td>
</tr>
</tbody>
</table>

### 3.3 Main items for lectures

1. Brief introduction to the geology, exploration and exploration in Western Depression of Sichuan Basin... Mr. Chen Zhaoguo.
2. The application of GeoX in China... Mr. Yang Dengwei.
3. Procedures and principles of the geological risk analysis of NPD... Ms. Inger Pedersen Fjaerstoft.
4. The CCOP Resource Classification System... Mr. Gunnar V. Søiland.
5. Netmeeting on new features in GeoX 5.2 and insight on the multisegment tool.

### 3.4 Main items for discussion

- Resources assessment (play) of tight reservoir
- Risk analysis of tight and fracture reservoir
- Fracture prediction
- Prediction of unmapped prospects
- Play economic evaluation
- Suggestion to China case study

### 3.5 Excursion
Dujiangyan
World Heritage
An ancient irrigation system built about 2300 years ago
Still in effect today

A major landmark in the development of water management
and technology
An immense advances in science and technology achieved in
ancient China
56 kilometers west of Chengdu

QingCheng Mountain
68 kilometers from Chengdu
1600 meters above the sea level
Boundless luxuriant forest and green trees in every
season
One of the birthplaces of Chinese Taoism
The most beautiful and quiet mountain

4. Second Workshop and long term plan for PPM Case Study

4.1 Agenda for second workshop and main topics for discussion and lectures

Topics:
(1) resource assessment of prospect
(2) economic evaluation of prospect

(3) Cost analysis of exploration, development and operation
(4) Production profile
(5) Define and evaluate marginal fields
(6) Sensitivity and scenario analysis
(7) Aggregate production forecast, investment and cost forecasts, cash-flow

4.2 First Expert Visit

Time: Jan. 15-17, 2004
Expert: Ben E. Law (?) From USGS
Topics:
1. Play and prospect resources assessment and economic evaluation on tight gas sandstone.
2. Methods on natural fracture prediction and geologic risk analysis on (fractured) tight gas reservoirs.

3. Prediction of subtle traps and resources assessment on subtle traps, including deep basin gas, lithologic trap, different composite traps.
4. Production techniques on multi-pay zone gas accumulations, such as the technique that one well produces gas from several pay zones separately at the same time.
5. Artificial fracturing techniques on very tight gas sandstone. (porosity 3-8%, permeability <0.01md).
4.3 Brief presentation of long term plan and topics to address in the coming workshops

Year 2003
- Resource assessment in the Western Depression of Sichuan Basin.
- Economic evaluations for play.
- First workshop.
- Annual report.

Year 2004
- Cost analysis of exploration, development and operation
- Production profile
- Define and evaluate marginal gas fields.
- Sensitivity and scenario analysis
- Aggregate production forecast, investment and cost forecasts, cash-flow
- Second workshop.
- Annual report.

Year 2005
- Identify adequate exploration and licensing strategies
- Apply national framework condition, fiscal systems and license regulation
- Sustainable and efficient national petroleum management and policy
- Third workshop.
- Final report.

5. Dissemination

The way knowledge, procedures and ideas from PPM are transferred within own organization and within host country.

A relevant research project has been set up by SINOPEC. Knowledge, procedures and ideas from PPM will be transferred within SINOPEC.

Following benefits for our organization can be expected:
- The way to do resources assessment and risk analysis
- Learning to do resources assessment and risk analysis by GeoX
- Economic analysis on a play, a prospect, a field
- Knowledge of fiscal regime in different country
- Management knowledge of petroleum resources
- Knowledge about fracture prediction and recovery methods of tight gas sandstone
6. Special Topic – Fiscal Regime

6.1 General overview of the Petroleum Fiscal Regime of the Country. When was it last revised?

The current petroleum fiscal regime was revised in 1997.

At the end of Pilot Test Period, the Contractor has the following options:

(1) to enter into the Development Period; or
(2) to enter into or continue work on an appraisal work program for a Gas Field; or
(3) to terminate the Contract.

“Remainder Oil” shall be divided into “CNPC Remainder Oil” and “Contractor Remainder Oil”. The Sharing Percentage is determined by referring to the factor (“X”) of each Oil Field for each Calendar Year which is determined in accordance with the following successive incremental tiers on the basis that the factor “Y” is a ratio as follows:

<table>
<thead>
<tr>
<th>Calculated Value of “X”</th>
<th>Sharing Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Contractor</td>
</tr>
<tr>
<td>When “X” is less than or equal to 1.0</td>
<td>72%</td>
</tr>
<tr>
<td>When “X” is greater than 1.0 but less than or equal to 1.5</td>
<td>50%</td>
</tr>
<tr>
<td>When “X” is 1.5 or greater</td>
<td>40%</td>
</tr>
</tbody>
</table>

“Remainder Gas” is divided into “CNPC Remainder Gas” and “Contractor Remainder Gas”. The Sharing Percentages shall be determined by reference to the factor (“Y”) of each Gas Field in each Calendar Year which is determined in accordance with the following successive incremental tiers on the basis that the factor “Y” is a ratio as follows:

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<td>40%</td>
</tr>
</tbody>
</table>
The Petroleum Contract of China

What are the INCENTIVES awaiting the INVESTORS?

- Exemption from taxes and duties for importation of materials and equipment for petroleum operations.
- Easy repatriation of investments and profits.
- Free market determination of crude oil prices.
- Special income tax rate of gross China income for subcontractors.
- Special income tax rate of China income for foreign employees of service contractors and subcontractors.

List topics that PPM should address in order to help the host organization come up with recommendations for improvements of the current fiscal regime.

- Introduce other country’s INCENTIVES to the host organization
- Analysis the advantages and disadvantages of the host country’s current fiscal regime
- Proposing fiscal regime which is beneficial for attracting foreign investments and increased petroleum activities

7. Participation in other case studies

7.1 Which case study teams are your country members of?

China participants are the members of following case study teams:
- Team China (host)
- Team Cambodia
- Team Indonesia
- Team Philippines

7.2 Which workshops have been attended, by whom?

Cambodia First Workshop
Participant:
- Mr. Guo Baoshen  China  Geologist/res.eng.
- Ms. Zhou Jin  China  Engineer
- Ms. Wang Xiaohui  China  Geologist

Cambodia Second Workshop
Participant:
- Mr. Guo Baoshen  China  Geologist/res.eng.
- Mr. Yang Dengwei  China  Geologist
- Mr. Wang Xin  China  Geologist

Philippines First Workshop
Participant:
- Mr. Li Shubing  China  Geologist
- Mr. Wang Liangguo  China  Economist
- Ms. Tang Hongjun  China  Reservoir Engineer
Indonesia First Workshop

Participant:

<table>
<thead>
<tr>
<th>Name</th>
<th>Country</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr. Long Shengxiang</td>
<td>China</td>
<td>Geologist</td>
</tr>
<tr>
<td>Mr. Wang Chuan</td>
<td>China</td>
<td>Geologist</td>
</tr>
<tr>
<td>Ms. Qiu Liwei</td>
<td>China</td>
<td>Geologist/Res.eng.</td>
</tr>
</tbody>
</table>

7.3 PPM/CCOP experience

- Did your country take active part in pre-PPM projects like REP and WGRA and OGRM. Are many of the earlier participants also active in PPM?

Yes. CCOP provided China many chances to take active part in pre-PPM projects, such as OGRM, WGRA, REP. We have learnt a lot from these projects. Such as knowledge on risk analysis, resource classification & assessment, economic evaluation, and so on.

Now, some earlier participants still take active in PPM project. They are:
- Mr. Yang Dengwei (OGRM, WGRA, REP)
- Mr. Long Shengxiang (WGRA, REP)
- Mr. Wang Chuan (REP)
- Ms. Zhou Jin (REP)
- Mr. Wang Liangguo (REP)

- How was the information about the PPM case studies distributed?

The information about the PPM case studies was distributed by the CCOP Website, emails, workshops, seminars and annual reports.

- Was it difficult to find people that were interested in participating?

In fact, PPM project is very interesting and very useful for exploring and developing petroleum resources. All participants are interested in the project.

People who are familiar with PPM, even CCOP are rare in China. We shall propagandize the aim and the procedures of the PPM project as possible as we can.

7.4 Experiences from workshops and seminar.

- Do you find the workshop agenda interesting and beneficial?

Yes, it is very interesting and beneficial. We think that the topic discussion and exercises are very useful. It helps us to gain the knowledge quickly and unforgettably.

And the excursion is also impressive! We share knowledge on PPM. At the same time, we share different cultures.
· How does the case study data and topics relate to challenges you face in your own country?

Though the geologic settings in western depression are quite different from other cases, some challenges in other country are similar to that in China case study. For example, we learnt at the first workshop of Philippines case study how to predict prospect numbers in the area where seismic lines are rare; By attending the first workshop of Cambodia case study, we know that the Multisegement of GeoX may be useful to us.

7.5 Dissemination.
· How do you apply(or plan to apply) the knowledge gained from the other case studies in your own organization?
(1) We plan to do resources assessment and risk analysis of prospects by Multisegement module.
(2) We shall predict prospects in longmenshan frontier area in the way Philippines do at the area where seismic lines are rare.
(3) Good experiences from other countries, especially those experiences on petroleum management, will be written in our final report. We think it will produce some effects on our petroleum policy and management.

· What are your recommendations in order for the case study participation to be useful in your organization?

First, take part in other country’s case studies actively, and discuss difficult problems with experts.

Second, study other country’s case studies methods of resource assessment, economic evaluation, petroleum policy and management.

Third, the host country experts should introduce more details about their methods and experiences.

8 Conclusion

8.1 Are the expectations to PPM met so far?

So far so good. Contributions PPM has made to China case study mainly are:
(1) Help us making out the agenda and main topics of China first workshop;
(2) Contact the source persons of the first workshop;
(3) Contact the experts of the first expert visit;
(4) Provide founds for us to take part in other case studies;
(5) Provide chances for us to share foreign experts’ experiences on resources assessment and risk analysis.
8.2 Good advise to the other three Case Studies host organizations, case study participants and PPM coordinators.

If host organizations can provide more data for foreign participants at the workshop, they may take more advantages from the participants.