

## MINING AND UTILIZATION OF CHINESE FUSHUN OIL SHALE

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*This paper describes geology, reserves, and open-pit mining of Chinese Fushun oil shale, as well as its utilization, including oil shale retorting, retort gas burning, carbon black producing and using shale ash as a building material.*

### Introduction

China is rich in oil shale resources. The proved oil shale reserves in Fushun, Maoming, and Huadian amount to more than 10 billion tonnes [1], yet extensive geological survey is to be done. The Fushun Mining Group Co., Ltd. is now the biggest mining company for mining and utilization of oil shale which is the by-product of coal mining. In Fushun, Liaoning Province, there are two open pits: west and east ones. East open pit is not in operation yet, while west one has been operated for more than 90 years, since 1918.

### Geology of Fushun Oil Shale

The Fushun mining area is located near to the Liaoning provincial capital, Shenyang city. It extends 18 km from east to west and 2-3 km from north to south. The west open pit at the western part of the Fushun mining area is 6.6 km from east to west, and 2 km from north to south. Oil shale with green shale on its top overlies there directly on the coal bed. According to the oil content, oil shale layers are divided into lean and rich ones. The lean oil shale layer, lying under the rich oil shale, has the average thickness of about 30 m. The rich oil shale layer has the thickness of 50-115 m, averaging 83 m. The total thickness of oil shale layer is larger in its west part and smaller in the east, varying in the range of 80--157 m, averaging 117 m. The oil shale deposit is shallow and gently dipping, with the overburden composed of clay, sand, debris and green shale.

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Fushun oil shale belongs to the Tertiary period of Cenozoic era, coexisting with coal-bearing strata between overlying Quaternary and underlying Cretaceous formations. Granites under the Cretaceous formation form the basement of the coal bed.

Fushun oil shale was formed in the interior depressions of a platform area. Some scientists believe that Fushun basin is of swamp origin, with underlying coal and overlying green shale, some explain that Fushun basin underwent two depositional stages, i.e. from swamp to lake. Coal bed was formed during the swamp stage, later a lake was formed on the subsidence of the basin, and oil shale was formed during the lake stage.

The Fushun west open pit has been mined since 1914. Till 2003, 480 million tonnes oil shale has been produced, now 70 million tonnes remain as proven exploitable reserves. However, east open pit has huge quantity of oil shale reserves not mined yet.

## Characteristics of Fushun Oil Shale

### Physical Properties

Fushun oil shale is a brown shale with laminated structure. Part of it is hard and part friable. This oil shale has high thermal strength. Its mineral matter is composed mainly of clay minerals and quartz, also some carbonates, sulphides, and ferrous compounds are present. Its organic matter is mainly kerogen with a little amount of bitumen. The organic matter content is about 20%, structural water content calculated 5.3% and relative density ranges from 1.8 to 2.7. The oil content is closely related to shale specific gravity – the lower specific gravity, the higher oil content, and the greater specific gravity, the lower oil content. The rich oil shale has specific gravity lower than 2.4, while that of the lean oil shale exceeds 2.4.

### Fischer Assay, Proximate Analysis, Elementary Analysis

*Table 1. Fischer Assay of Fushun East and West Open Pit Oil Shale, wt.%*

Indices	West open pit	East open pit
Shale oil	6.69	6.03
Water	3.88	2.03
Retorted shale	86.13	89.74
Gas + loss	3.30	2.20

Based on the Fischer Assay of 42 bore samples of the Fushun west pit oil shale, the average shale oil yield of rich oil shale accounts for 4.18–7.61%, that of lean oil shale 1.11–4.35%. The representative Fischer Assay data of rich oil shale is given in Table 1 [1]. Data of proximate and elementary analyses of Fushun west open pit rich and lean oil shale are shown in Table 2.

## Mining of Fushun Oil Shale

Fushun west open pit oil shale has been mined for more than 90 years. The oil shale layer lies upon the coal bed; it is the by-product of coal mining. Till now 489 million tonnes oil shale has been mined out. Due to thin overburden and gently dipping deposit, Fushun west mine coal and oil shale are open-pit mined. Open-pit mining has the following advantages over underground work:

- Lower mining cost, only about 35–50%
- Shorter construction time
- Higher productivity, 3-5 times higher than that of underground mining
- Better operation conditions, safe working under open air
- Less losses of oil shale, mining yield reaches 90–100%

Fushun west open pit mining is processed in horizontal bench type, the mining bench height usually amounts to 6–8 m. Each working bench extends for about 5 km and is equipped with several quarrying machines and transport railway line.

For normal operation, open-pit mining includes two mining systems: one for preparation work, i.e., stripping process, including hole drilling, blasting, quarrying, transporting, and dumping (to the dumping yard with sand, rocks, lean oil shale, etc.); the other for exploitation work, including quarrying and transportation of rich oil shale to the retorting plant.

Mining operation in the west open pit is processed from south to north, movable tracks extend in a zig-zag way down to the working depth. Excavated materials are sand, green shale, tuff, basalt, oil shale (as product) and coal (as product). Except for sand, the others must be first drilled and blasted. The drilling machines are of the type GZ-160 and YQ-150A, the drilling depth can reach 24 m. Power-driven shovels of the type WK-10 and WK-4 with the capacity of 10 and 4 m<sup>3</sup>, respectively, are used for quarrying. Totally more than ten shovels are in operation now.

Electrified wide railroads are used to transport rich oil shale to the retorting plant, and rocks, lean shale and surface coverings to the western and eastern dump yards. Electric rail trains used for transport can haul twelve dump wagons, each with the volume of 27 m<sup>3</sup> and capacity of 60 t.

The total mileage of railroad in the west open pit exceeds 400 km. Due to the fact that the mining level has already reached the depth of more than 300 m, transportation of long haulage distance from the surface to the working level and back to the dump yard takes much time, one transit cycle is as long as five hours.

*Table 2. Proximate and Elementary Analysis of West Open Pit Oil Shale*

Indices	Oil shale	
	Rich	Lean
Proximate analysis:		
Ash, %	70.6–78.1	77.9–81.0
Volatile matter, %	13.4–20.2	8.3–11.1
Q, kJ/g	4.5–7.6	1.2–3.0
Elementary analysis, %:		
C	11.55	
H	2.06	
O	4.29	
N	0.50	
S	0.59	

## **Comprehensive Utilization of Fushun Oil Shale**

### **Production of Shale Oil**

In Fushun, the retorting of oil shale for producing shale oil has the history of more than seventy years. From 1930 to 1982, 426 million tonnes oil shale has been processed, and 14 million tonnes shale oil and 2.45 million tonnes ammonium sulphate produced. In the fifties of the last century, Chinese shale oil industry developed rapidly, covering large part of liquid fuel production needed in China. During this period, Fushun Refineries No. 1 and No. 2 had the largest capacity of oil-shale retorting reaching about 19.20 million tonnes oil shale in 1959. In the sixties, due to exploitation of cheap crude oil, the production of shale oil decreased gradually. In the eighties, the oil shale retorting units of Fushun Refineries Nos. 1 and 2 and of Maoming Refining Plant were shut down successively.

Based on the plentiful quantity of oil shale produced as the by-product of coal mining, in 1987 a program of annual production of 120,000 tonnes shale oil was proposed by Fushun Bureau of Mines. It was approved by China National Planning Committee in 1988. A three-phase construction plan was completed in 1995, with three retorting blocks equipped with sixty Fushun-type retorts, consuming 3 million tonnes oil shale and producing 90,000 tonnes shale oil yearly [2].

Fushun Shale Oil Plant began retorting in 1991. Till 2003, 25 million tonnes oil shale were processed and 750,000 tonnes shale oil were produced. In 2003, 102,000 tonnes shale oil were obtained, and significant economic and social benefits were gained [3].

Now the fourth block (twenty retorts) is being built in Fushun Shale Oil Plant, it will be put into operation in 2004. It is considered to build an ATP retort to utilize Canadian technology for processing small-particle oil shale which cannot be treated in Fushun retort.

Shale oil is now sold as fuel oil, the surplus retort gas is partly used in boilers for producing steam for plant and household use, and a part of surplus gas is used in local internal combustion engines as fuel for producing electric power. Four sets of internal combustion engines equipped with electric generators were built (each set has the capacity of 500 kW). Shale oil can be processed for producing high-quality light liquid fuel and chemicals. In Fushun Plant, a small part of shale oil produced is now used with yearly production of 2000 tonnes for producing carbon black by spraying method.

### **Production of Building Materials from Shale Ash**

#### *Bricks*

A brick factory has been built and operated in the Fushun mining district with the yearly production of 60 million bricks. The main raw materials are:

shale ash from the retorting plant, green shale from the coal open pit and waste coal (Table 3). Their volumetric proportion is:

shale ash : waste coal : green shale = 60 : 20 : 20.

Table 3. Composition and Heating Value of Raw Materials for Bricks

Items	SiO <sub>2</sub> , %	Al <sub>2</sub> O <sub>3</sub> , %	Fe <sub>2</sub> O <sub>3</sub> , %	CaO, %	MgO, %	Ignition loss, %	Heating value, kcal/kg
Shale ash	49.96	18.04	9.44	1.73	1.26	12.78	462
Waste coal	36.72	15.95	10.96	2.49	1.04	28.34	1178
Green shale	14.51	15.32	9.28	5.79	3.64	15.50	
Their mixture	45.83	4.25	6.45	2.50	1.39	16.82	555

Heating value of the raw material mixture is sufficient for combustion to supply thermal energy for preparing building materials. The mixture has the plastic index of 7.75, therefore belonging to medium plastic materials.

Bricks are burned in a tunnel furnace. The processes controlled by micro-computer are as follows:

Raw material grinding – mixing – aging – pressing –  
– moulding – drying – incineration

The produced brick has the dimensions of 240 × 115 × 90 mm, and 30-percent porosity (Table 4).

The data indicate that the quality of the bricks produced meets specifications of the superior-grade brick GB13544-2000, whose strength grade is MU20.

Table 4. Specifications of Bricks

Item	Specification	Measured value	Evaluation
Compressive strength, MPa:			
average value	> 20.0	21.7	Pass
standard value	> 14.0	14.8	Pass
Porosity, %	> 25	35	Pass
Frosting		None	Good
Lime breaking		None	Good
Anti-freezing		None	Pass

The factory has reached the production of 60 million bricks yearly and intends to expand to 300 million porous bricks for high buildings.

#### Cement

In the Fushun district, a cement factory has been built and operated with yearly production of cement 90,000 tonnes. Shale ash from oil shale retorting plant has been used as one of clinker raw materials. Small amount of residual carbon in shale ash favors clinker sintering and saves thermal energy. The shale ash quantity used in clinker raw materials is about 9–13%. The quality of the cement produced meets standard specifications. The annual production of cement is being expanded to 200,000 tonnes. A new advanced dry process with burning in a rotary kiln is to be used. The plant will be put into operation in 2004.

### Production of Electricity

A program of establishing an electric power station with the capacity of 340,000 kW by using oil shale as boiler fuel has been studied. The investment will be afforded by a foreign company.

### Conclusions

The coal reserves in Fushun are decreasing due to their large-scale exploitation. However, at Fushun west open pit more than 70 million tonnes oil shale still remain, and east open pit has vast amounts of oil shale reserves unexploited. The oil shale amount mined in 2003 reached 4,300,000 tonnes; that used for retorting in 2003 accounted for 3,000,000 tonnes. Hereafter, when the fourth block (twenty Fushun retorts) is put into operation, the total four blocks of Fushun Shale Oil Plant will consume 4,000,000 tonnes oil shale yearly.

Fushun Shale Oil Plant has retorted 25 million tonnes oil shale and produced 750,000 tonnes shale oil from 1991 to 2003. In 2003, 102,000 tonnes shale oil were produced and significant economic and social benefits were made. A project of expanding the annual shale oil production by 200,000 tonnes is going on, foreign advanced retorting technology is being considered.

Fushun Shale Oil Plant produces carbon black by using a small amount of shale oil. The surplus retort gas with low heating value is being used in internal combustion engine for producing power.

Oil shale ash from Fushun retorts is partly used for producing bricks and high-quality cement.

It is also considered to build a 340,000-kW power station using oil shale as solid fuel.

This indicates that Fushun oil shale industry has made great contribution to Chinese economy, and the comprehensive utilization of Fushun oil shale is promising.

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