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PYRITE MINING AND SULPHUR PRODUCTION AT XINGWEN, CHINA

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Abstract: In the mountainous Xingwen region of Sichuan, a group of small pillar and stall mines produce pyritic mudstone and coal. These are the raw materials for sulphur factories, which are a mainstay of the local economy.

Xingwen county lies in the limestone fold mountains forming the southern rim of the Sichuan Basin in the very heart of China. It is 200 km southwest of Chongqing, and 70 km southeast of Yibin, both of those cities standing beside the mighty Chang Jiang (Yangtze River) which drains through the basin. Most of Xingwen's people are involved in farming around its many rural communities, but the county also has some spectacular limestone karst with tourist caves and stone forests, and also an important mining belt. Both coal and pyrite are mined, and their output feeds a series of sulphur factories.

The geology of Xingwen is dominated by a periclinal anticline with its axis roughly east-west. This is breached to leave an ellipse of inward-facing escarpments formed by the strong Permian limestone of the Maokou and Qixia Formations. The limestone is overlain by Permian coal measures, and these in turn are capped by Triassic sandstones. Immediately above the limestone, the lowest few metres of the coal measures contain a coal seam and a pyritic mudstone.

Along the southern side of the Xingwen anticline, the two mineral beds dip gently into the hillside which rises above the dip slope of the limestone (Plate 1). Their outcrop is marked by a line of villages - Xingyan, Daxue and Dayuan - whose existence depends on sulphur production. Pyrite mines and coal mines number at least twenty each along 20 km of outcrop, and there are more mines further round the anticline.

Plate 1. A new mineral processing plant stands on the edge of the limestone karst near Xingyan. The slopes behind rise through the coal measures, with the outcrops of the main coal seam and the pyrite ore at their foot.

Like in so many villages in the mountains of China, facilities in these are fairly basic. A single road now links them, and there is electricity, but water supplies are rather patchy. There are a few shops, a daily bus to the county town, and two hotels near Xingyan which try to catch visitors to the caves and country park on the limestone. To match this rather minimal infrastructure the mines are all small operations, totally unlike the massive modern coal mines elsewhere in China.

THE COAL MINES

Just 7 metres above the limestone the lowest coal seam is the one most extensively worked, though others higher in the succession are also productive. The mines are all drift workings from outcrop; they are worked horizontally along the strike where the topography allows, but most have to follow the seam downdip. Their working is essentially pillar and stall, with patterns to accommodate local structures. Coal cutting is by hand. Parts of the seam reach about two metres thick where the larger mines are each worked by perhaps 20 or 40 men. Most of these have rail tracks, on which tubs are pushed by manpower.

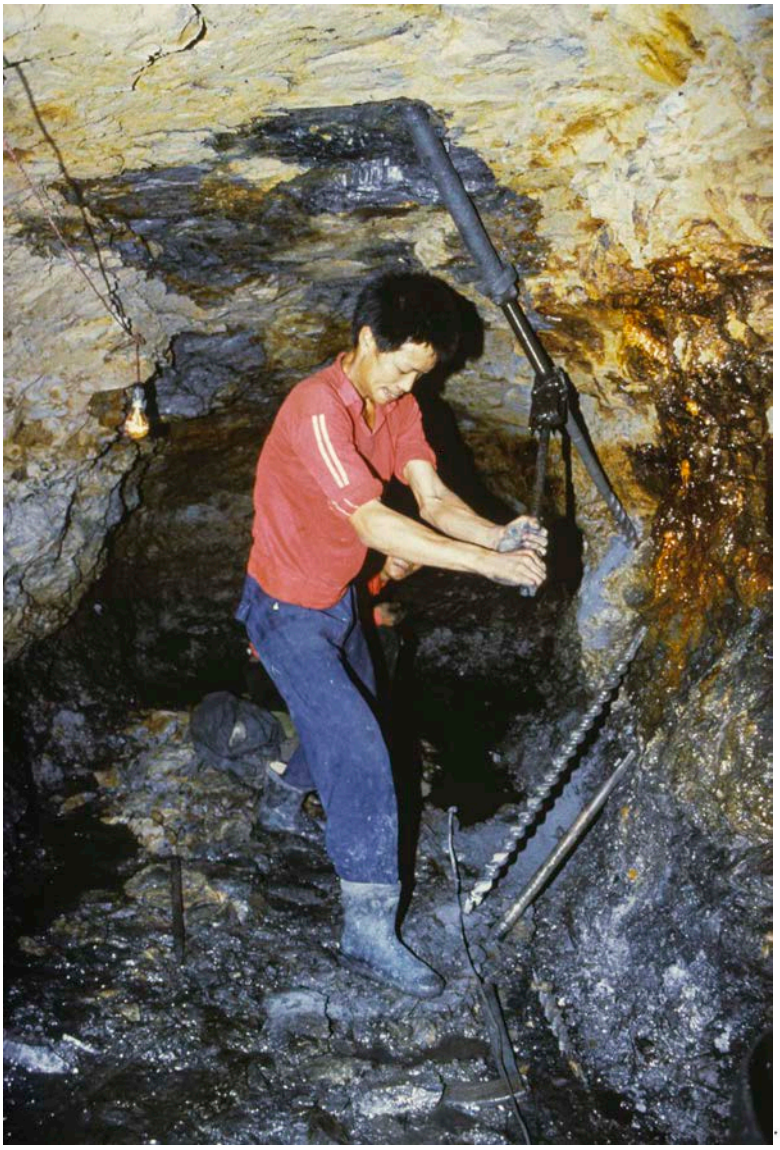
The smaller coal mines are tucked into the thinner parts of the seam, and are worked on very primitive levels. In many the coal is hauled to the surface in baskets mounted on wooden skids; a single loaded sledge is just dragged through the inevitable mud by a man leaning almost horizontally under the strain of a shoulder loop. The smallest of all the mines are worked by boys of various ages well under 16, probably as a little bit of private enterprise. One mine near Xingyan is worked by two brothers; the older boy hews the coal with a pickaxe, while the younger half of the team drags laden baskets to daylight through a drift which is well under a metre high (Back cover bottom left). In full production mode, they win over half a tonne per hour.

THE PYRITE MINES

Within the Coal Measures, the mudstone succession contains a single bed about 2 metres thick which is rich in pyrite; its base is just 1 metre above the limestone. The pyrite occurs in crystal aggregates and nodules, each 1-20 mm across. Sulphide forms about 25% of the rock mass, within a matrix of hard calcareous

Plate 2 (above). A miner in full safety gear in a level of a small pyrite mine near Xingyan, with openings on the right into larger rooms.

Plate 3 (below). Drilling a shothole in Xingyan pyrite mine. The screw jack is braced against a roof notch to drill obliquely down into the wall.



mudstone. This one bed is the sole pyrite source and is mined by numerous small drift workings all along the outcrop. The proximity of the coal and pyritic beds gives scope for problems with super-imposed pillars, and some mines do have underground links between the two worked horizons.

The mines work by partial extraction, with a pattern rather like some of the old post and stall coal mines in Britain. From access drifts only 2-3 metres wide (Plate 2), short spur drives are opened up into rooms generally about 6-8 metres in diameter. Overall extraction reaches about 65%, leaving support pillars no less than about 3 metres across. The roof is generally good, but the wider rooms require timber props to prevent small rockfalls; props are not on a scale to provide total support (Back cover top). It appears that rooms are progressively widened until a threat of failure is perceived; but total collapses do occur, and lead to sections of the mines being prematurely abandoned.

The pyritic mudstone can only be extracted by blasting. Shotholes are drilled by hand; a screw rock drill is rotated slowly under a very high axial load, which is provided by a screw jack braced against the opposite wall or a roof notch (Plate 3). Holes are charged with sticks of locally produced explosive, and are fired with electric detonators. Safety practices are spectacularly casual. The blasting superviser in one mine at Xingyan was seen clambering about underground with plimsolls on his feet and with no helmet or light; he wore a normal suit jacket with added internal pockets - for explosive sticks on the right, and detonators on the left. After firing, the dust clears by natural airflow between mine entrances at different levels. There is no forced ventilation, though some mines have lighting - with 20 watt bulbs strung out at 10 metre intervals. Broken ore is raked by hand and loaded into handcarts which are hauled to daylight. Some of the larger mines do have rail tracks for hand-pushed tubs.

MINERAL PROCESSING

Treatment of the mineral product varies from mine to mine. At the main Xingyan mine, blocks of ore are broken to lumps of 50-100 mm by hand hammering; the ore grade is then raised by hand cobbing, where the lumps with more visible pyrite are selected, and this material is taken in handcarts down the hill to the smelting furnaces. A few mines at Dayuan produce an ore of higher grade; rail tracks lead directly from the mine onto the top of the furnaces, where the mine tubs are tipped directly into them.

Some of the smaller mines near Xingyan have no road access and have no adjacent furnaces, and also produce ore with a smaller grain size of the pyrite. Their ore is reduced to less than about 3 mm in small jaw crushers, and is then washed on vibrating tables, but a lot of mineral is still lost. The product is reasonably pure

granular pyrite which is taken by donkey to the nearest road. There are also a few more modern mineral processing plants which produce pyrite concentrates.

THE SULPHUR FURNACES

At the heart of each sulphur factory there is a row of 20 to 30 furnaces (Back cover bottom right); the unit at Xingyan is smaller than those at Daxue and Dayuan, but the processes are typical of all the Xingwen sites. Built of mortared limestone blocks, a single furnace is about three metres square and four metres high. Cartloads of upgraded pyrite ore and coal, both minerals in lumps of about 50 mm, are tipped in through a hole in the roof, which is then sealed with an iron lid to prevent excess air entry during burning. Fired from below, the burning coal roasts the pyrite to produce sulphurous vapours. These escape through a side opening into a condensation chamber where much of the sulphur is deposited on the cool walls. The fumes continue through horizontal flues which converge on a tall chimney. Large amounts of sulphurous gases escape through the poorly sealed brickwork of all the structures, creating massive smoke pollution and a thoroughly evil environmenmt in which to work.

When the furnace load has burned out, the top is reopened; the remaining slag is broken with long crowbars, and is then raked out from below, directly onto ever-growing slag heaps. These extend onto the limestone with slip-off slopes up to 40 metres high. They consist mainly of silicates and iron oxides, but there is still a proportion of unburned pyrite. Drainage from them is uncontrolled, and along with waste from some of the smaller mineral processing plants, flows directly onto the limestone and into the underlying caves. The sulphide input starts reactions which culminate in spectacular gypsum deposits in some caves; it also produces massive pollution of the underground air and water, fortunately away from the tourist caves (Waltham and Willis, 1993; Bottrell, 1993).

At the same time that the furnace is raked out, a door is opened in the side of the cooled condensation room, and large blocks of sulphur condensate and dripstone are broken from the walls (Plate 4). These are then carried in baskets, paired on bamboo yokes, up the hill to the refinery. There the sulphur is remelted in large woks over coal fires. At 180°C the molten sulphur becomes a red viscous liquid, but further heating turns this to a yellow and more fluid melt. Impurities either settle out or float off, and the refined sulphur is poured through secondary vats and into moulds which are cooled in water (Plate 5). These cast blocks are Xingwen's end product, and are despatched from the county by road.

Though working conditions in the mines and on the furnaces are not good, the opportunities are welcomed as an alternative to the farming - which is less lucrative in these

Plate 4 (above). Blocks of sulphur are shovelled out of a cooled condensation room adjacent to its furnace in the Xingyan sulphur factory.

Plate 5 (below). Molten sulphur has been poured through the vats to fill the cooled bowls in the final production stage at the Xingyan sulphur factory.

Plate 6. Waste heaps spread-out on each side of the Xingyan sulphur furnaces. Tip heaps on the left are sub-grade ore and also waste from an older generation of furnaces higher up the slope. Debris on the right is the top end only of the great piles of slag raked-out from each furnace after each firing. Downslope drainage takes contaminated water on to the limestone towards the right. The prevailing wind is to the left and air pollution restricts plant growth on the higher slopes.

mountainous limestone regions than it is on the fertile plains. Atmospheric and river pollution is a serious problem both above and below ground (Plate 6). The potential for a tourism economy based on the karst and caves heightens the environmental conflict with the mining and industry; there is no simple solution, and the industry continues to thrive. Through its evolution in a fairly isolated part of rural China, the Xingwen sulphur industry has become a fine example of mining and smelting in a style which perhaps bears comparison to historical records of mining in some parts of Europe.

REFERENCES

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The mines and sulphur factories at Xingwen are very definitely not open for official access. These few notes are the result of personal observations on regrettably brief visits, and they owe much to the immense hospitality of the miners and workers, at Xingyan in particular, despite minimal communication across the language barrier.

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Photographs in the original published journal were in black-and-white only.
The photographs on the following page appeared on the back cover of this issure of *Mining History*.

Pyrite and sulphur production at Xingwen, China. *Top. A room in a small pyrite mine near Xingwen. The miner is drilling a new shothole to widen the room, while props are already installed under loose sections of the roof.*
Bottom left. A young lad drags a skid-mounted basket of coal out of the mine that he works with his brother near Xingyan.
Bottom right. One of the lines of 20 furnaces at the Xingyan sulphur factory, at Xingwen, China, with limestone hills across the skyline. The arched roofs are on the condensation rooms just to the right of their matching furnaces. Some of the roof holes on the furnaces are open for recharging, whereas others are sealed during firing.