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MINING SISTEM OF THE EL-LAJJUN OIL SHALE

The opportunity of production of oil shale on El-Lajjun deposit is considered. The rational systems of development of a deposit are offered and their economic feasibility is proved.

СИСТЕМИ РОЗРОБКИ ЕЛЬ-ЛАЮНСЬКОГО НАФТОВОГО СЛАНЦЮ

Розглянуто можливість видобутку нафтового сланцю на Ель-Лаюнському родовищі. Запропоновано раціональні системи розробки та обґрунтовано їх економічну цілеспрямованість.

The oil shale deposit of El Lajjun is situated 110 km south of Amman between Karak and Qatrana. The deposit consists of Upper Cretaceous bituminous marl in the Lower Chalk-marl Unit and the uppermost Phosphor Unit occurring in a 25 km^2 garben-like structure

Mining study

The mining study includes a pre-selection of the first exploitation area. After a determination of the opencast development different mining methods are presented.

1. Development of the open cast

After the principle determination of the first exploitation area the methods of opening and developing the open cast have to be investigated. In this context the location of the retorting plant, of the stockpile an' of a suitable site for the external overburden dump have to be considered as well as the surface water drainage. The geological report has proved the terrain north and west of the exploration bore hole No.54 as being optimal for the location of the retorting plant. Bordered by two wades it is suitable with regard to the topography and is situated outside of the deposit itself.

An area south-west of the plant site offers the possibility of intermediate stockpiling of oil shale as a buffer between mine and plant to guarantee a continuous supply of the plant. This terrain is also bordered by two wades and situated outside of the minable reserves. For dumping the overburden of the open-cut an area situated between the road Karak-Qatrana and plant site at the exploration bore hole No.56 could provide sufficient dumping capacity, especially if t mine is opened from the northern part of the selected exploitation area.

1.1. Selection of the mining method

For open cast mine planning the determination of the mining method should be considered first of all, i.e. how to advance the open cast benches across the deposit. Basically there are two methods, parallel mining and pivot mining.

1.l.l. Parallel mining

Parallel mining moves the open cast benches parallel to each other into the mining direction. The internal overburden dump follows in the same way (fig. 1). A characteristic of parallel mining is the increasing distance between the operation levels and the starting point, for example a stationary crusher. Therefore the hallway for the material is getting continuously longer. By way of contrast the haulage distance for the overburden remains constant after having established an internal overburden dump. The disadvantage of a continuously enlarging haulage distance for the mine' material

stands up against the advantage of an almost constant bench . length *and* against a relatively simple mine *layout.* In general parallel mining is applied when exploiting long rectangular areas.

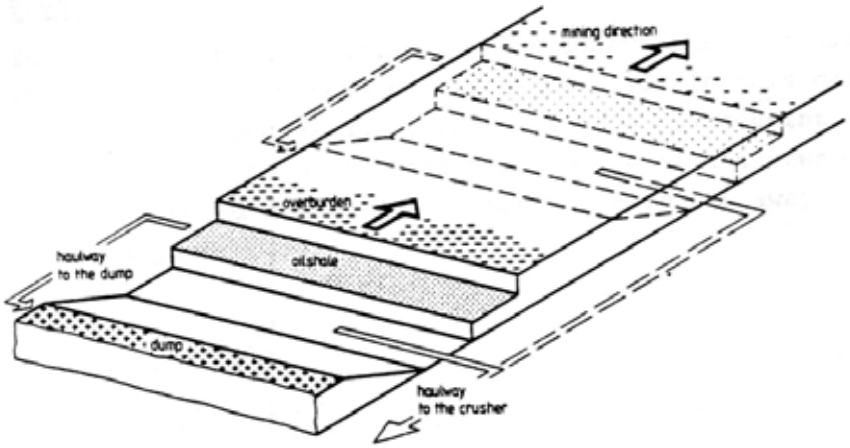

Fig. 1 – Parallel opencast mining method

1.1.2. Pivot mining

In roughly circular ,triangular or square shaped areas the pivot mining method should be applied . In this case the open cast benches are turned around a pivot point (fig. 2). In pivot mining the mass center of the open cast is located two thirds of the bench length away from the pivot point .In pivot mining all types of haulage systems can be used. Truck hauling offers special advantages and a simple design of the pivot point. The mining operation turns around the stationary installations at the pivot point, such as energy supply, water pumping, primary crushing, warehouses and repair shops, thus keeping a constant distance offering some advantages concerning operation control and organization.

1.2.2. Mining method and mine development

The above mentioned considerations make it clear that the oil shale deposit of El Lajjun can optimally be mined by pivot mining. It is recommendable to mine the exploitation area in two phases. Phase I includes the northern part. Its pivot point (pivot point I) is located near the exploration bore hole No.50 .For phase II exploitation the pivot point is moved to the south, i.e. into the center of the line between the exploration bore holes Nos.71 and 68. This proposal especially takes the surface water control during wet season into consideration.

Phase 1 is opened from pivot point I into an eastern direction at the northern slope of Wadi Khabra. The mine is turned counterclockwise, in a semi—circle, south of the road Karak-Qatrana. The final position of phase 1 open cast points west parallel to a wadi. north of the exploration bore hole No.67. During the operation of phase 1 the drainage of the surface water from the catchment area is ensured by the existing wadis. The open cast area itself has to be kept dry by water draining and pumping.

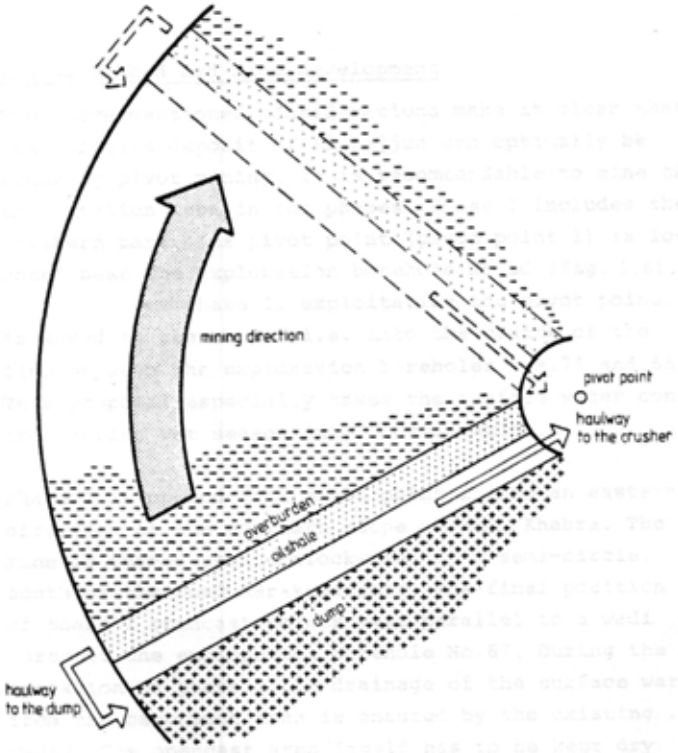

Fig. 2 – Pivot opencast mining method

Simultaneously to phase 1 operations phase II open cast has to be opened as a connection between pivot point 1 and II. Phase II opencast is turned counterclockwise as well, along the final position of phase 1, then along the graben-border and finally along the traverse between the exploration bore holes Nos.99, 62 and 66 to a final position east of bore hole No.104.

In order to keep the surface water of the catchment area off phase II open cast again the existing wades are used. A water drainage is installed additionally along the final position of phase 1 mine. This drainage is continuously extended along the final slope at the western border of the open cast in order to drain the surface water from the western area along the open cast border into a northern and eastern direction to wadi khabra.

2.Opening

Phase 1 is opened from pivot point 1 at the slope east of the exploration bore-hole No.50. Phase II is also opened from pivot point 1 with a box-cut directed to pivot point II south of the exploration bore hole No.71 The overburden of phase 1 opening has to be dumped on an external dump, whilst the overburden of phase II opening can be dumped on the internal dump of phase 1. The oil shale mined from phase II opening is hauled to the crusher station at pivot point 1.

2.1 Phase 1

The most suitable opening for phase 1 open cast is an east-running slope-cut along Wadi Khabra, considering the topography as well as the thickness of overburden and oil shale. This procedure ensures a fast reach of the oil shale. Furthermore the quantity of overburden be dumped outside is reduced to a minimum.

2.1.1 Slope-cut opening

The opening operation comprises all work up to the moment when production starts. The volume of overburden depends on the opening length and its cross-section geometry. Phase 1 opening has a length of 1,200 m.

When opening the slope-cut two oil shale levels have be prepared. Most overburden can be mined from one level only, at least in the slope region. Benches are 40 m wide with 80 angled slopes. This results in an overall slope angle of about 300 depending on overburden and oil shale thickness.

The deepest level on the underlying strata of the oil shale should have an operation width of 50 m in order avoid handicaps in operation by the internal dump, especially during wet season. Finally it is recommended to leave a 50 m wide safety pillar along Wadi Khabra to protect the opening from engrossing of water The volume of overburden to be mined from the opening is calculated at about 1.5 million m^3. This volume has to be dumped on an external overburden dump.

2.1.2 Pivot point 1

As mentioned before the slope-cut opening is developed the planned pivot point for phase 1 open cast near the exploration bore hole No.50. At this pivot point all overburden and oils ale levels are linked together and connected with the mine entrance. All mined oil shale hauled to this point and there dumped into a primary crusher. Therefore the pivot point is the or area of the open cast which does not change its location . The level linking ramps have to be established in a that, on the one hand, the pivot point needs only the least pre-work to be done and, on the other hand, can used during the entire life time of the open cast. The layout of pivot point 1 is shown in fig. 3.

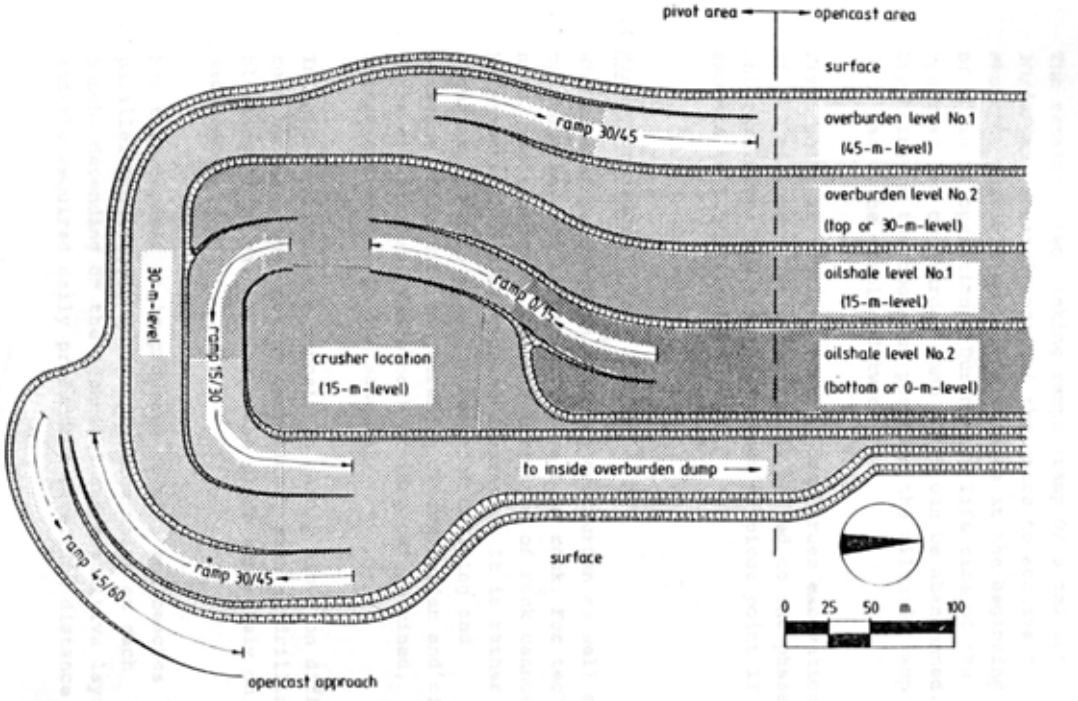

Fig. 3 – Layout of pivot point II for phase II opencast

The primary crusher station is located south of the pivot center. The truck dumping level at the crusher should be identical with the top of oil shale layer in order to avoid water problems.

The two oil hale levels of the open cast are linked to the crusher station level by two ramps. For a 15 m main bench height the ramps need 150 to 200 m of length to guarantee a 10 % maximum incline, Whereas the oil shale ramps can be used during the entire life time of phase 1 the overburden ramp has to be dislocated once. After starting normal operation the overburden can be hauled partially via the pivot point to the internal dump. The excavation volume for pivot point 1 amounts to some1 million m^3 including the crusher location. This overburden has to be hauled to the external overburden dump.

2.1.3.External overburden dump

The overburden removal of phase 1 opening amounts to 2.5 to 3 million m^3 i.e. some 4.5 million m^3 loose supposing a swell factor of 1.5.The area at the exploration bore hole No.56 outside of the deposit is the preliminary selected site for the overburden dump. This area is bordered by the road Karak-Qatrana, by Wadi Khabra and by the border of the exploitation area. This terrain covers about 0.5 million m^3. At a maximum dump height of up to 15 m this area has a capacity of 7 million m^3. Hence the requirements for the overburden of phase 1 opening are easily met.

2.2 Phase II

After the production start of phase 1 open cast, phase II open cast has to be opened early enough to ensure that the final production target can be reached without any delay. For this opening a box-cut is excavated start from pivot point 1 towards the exploration bore hole No.68 up to the planned pivot point II. Subsequently the pivot point itself is advanced including the main primary crusher station.

2.2.1 Box-cut opening

Within phase II opening the oil shale, about 30 m thick is completely covered by some 30 m of overburden. Therefore the deposit can only be opened by a box-cut, as shown in fig. 4. The box-cut overburden is excavated on two benches, each of them about 40 m wide, and hauled to the internal dump of phase 1 open cast. In the oil shale layer self there are also two levels established. The deepest level on the underlying strata of oil shale should be 50 m wide. The final slope is secured by 5 m wide berms, so that the external slope does not exceed an angle of 60.This concept is designed in a way that the existing infrastructure at pivot point 1 can be used during entire opening work. Especially the box-cut can be developed from the different levels of pivot point without any additional ramp. The box-cut opening has a length of 800 m About 4.3 million in of overburden have to be mined. Addition 3.5 million tons of oil shale has to be hauled from the box-cut to the crusher at pivot point 1.

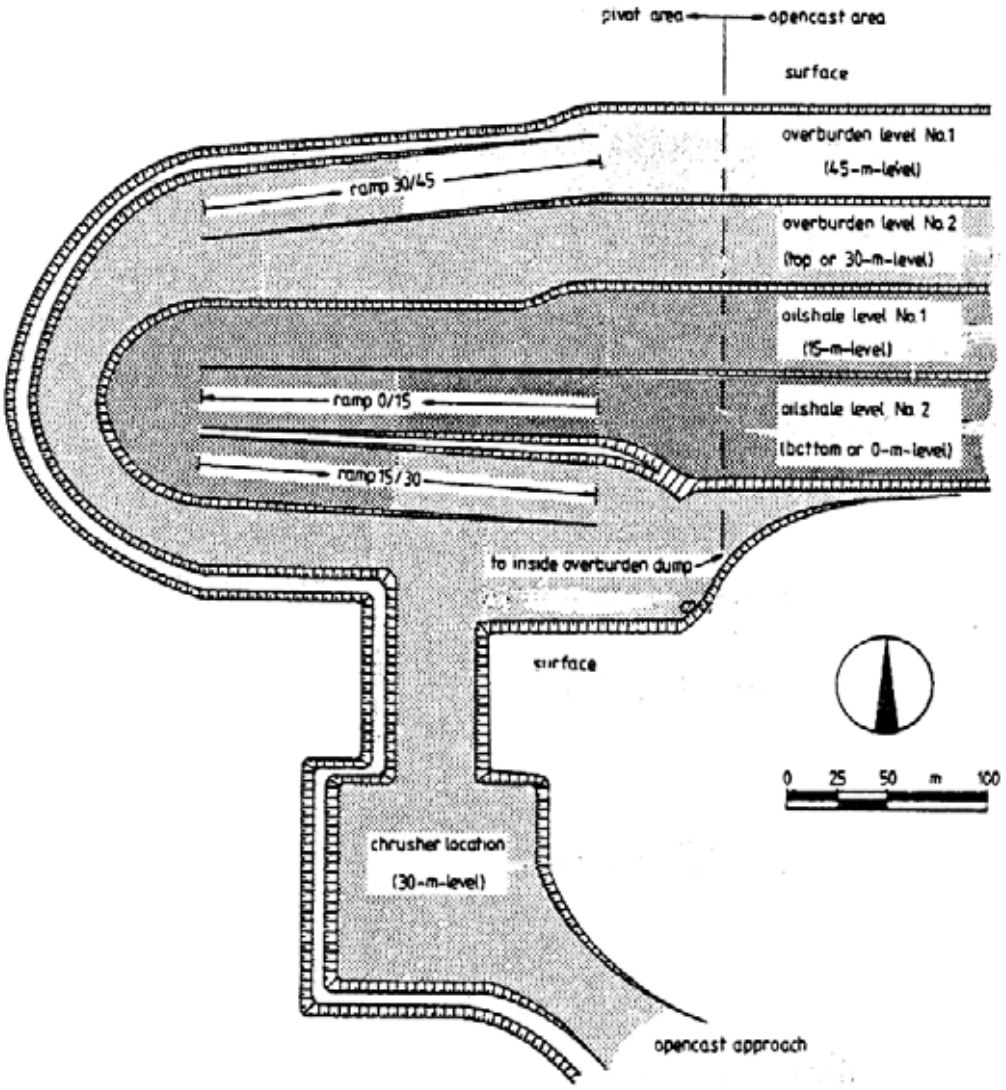

Fig. 4 – Layout of pivot point I for phase I opencast

2.2.2 Pivot point II

Beginning at the end of the box-cut opening pivot point II is established. The layout is shown in fig. 5.The crusher site is situated on the upper oil shale level, about 15 m above the underlying strata. That provides sufficient safety against high water. Length of the haulage ramps can be kept short. The crusher station is located in the center of the pivot point. The mine entrance and two bench linking ramp are situated in the south-east corner of the pivot point. The remaining two linking ramps (ramp 0/15 and ramp 30/45) are located north of the canter to achieve the shortest possible haulage distances at the beginning of phase II operations. During the life time of the open cast the overburden ramp 30/4 5 can be abandoned Depending on the open cast position the oil shale ramp 0/15 has to be displaced twice Pivot point II requires a total overburden excavation of 3.2 million m^3 which has to be hauled to the phase 1 internal dump. The oil shale output of pivot point 1 amounts to 1.5 million tons.

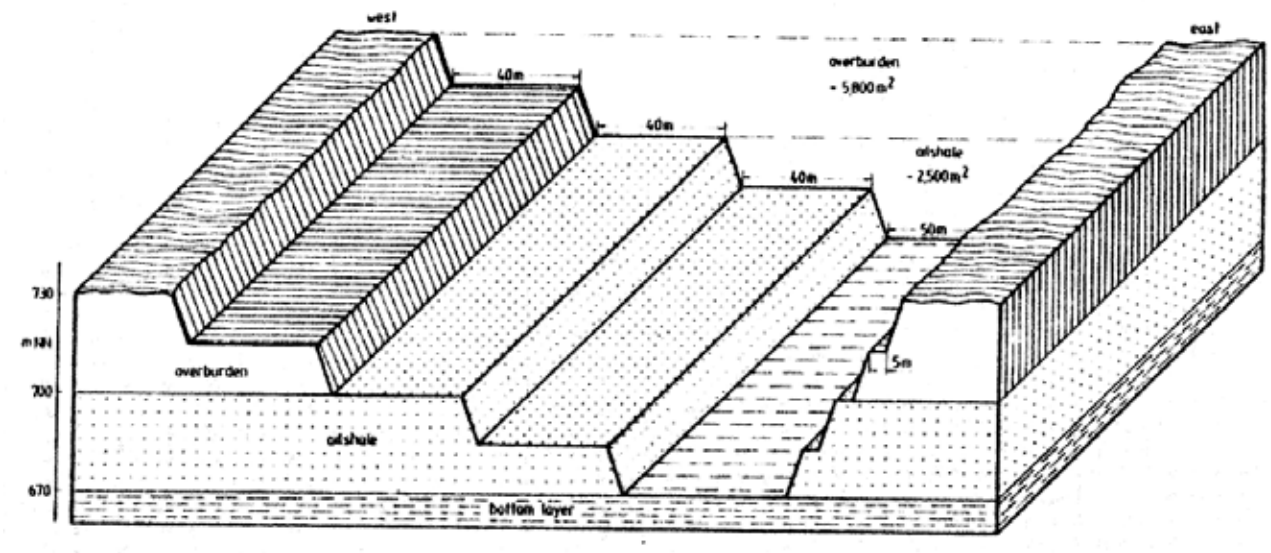

Fig. 5 – Box-cut opening for phase II opencast

2.4 Mining procedure

Within most parts of the deposit overburden as well oil shale has to be classified as hard rock. For technical and economical reasons this type of rock cannot be mined with a bucket wheel excavator. It is rather necessary to recover it by means of drilling and blasting. Structure and strength of overburden and shale are similar.

Hence both of them can be mined, loaded and hauled in the same way. In hard rock pits the deposit is mainly mined on different benches. The working operations, such as drilling blasting, loading, hauling, take place separately on each bench. For this deposit it is proposed to mine the benches parallel with one to three operation units on each bench, depending on the technical and capacitive layout and the required daily production rate. The distance between two operation units (blocks) is mainly depending on the blasting method and the length of the blasting round. The smallest distance results from the round length and the necessary width for the hauling. The stability of the rock determines the slope angle and the bench height. The maximum bench height depends on the range of the drilling and loading equipment. A mean bench height of 15 m and a slope angle of 80 are suggested. The height can increase up to 20 m depending on oil shale and overburden thickness. As far as deposit is explored up to now four benches, two shale and two in overburden, have to be established (fig. 6). For areas with more than 40 m thickness of oil shale or overburden an auxiliary bench to be added.

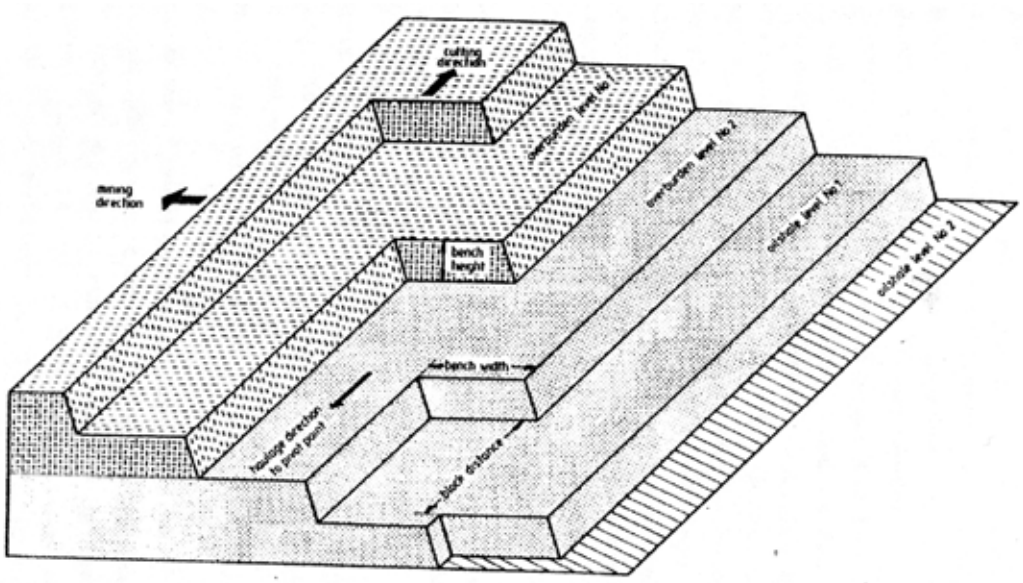

Fig. 6 – Layout of benches for the opencast

The width of benches is mainly depending on the selected blasting method and on the loading equipment. As explained in detail later on it is recommended to the benches in blocks, the working direction rectangular to the mining direction. The width *and* the number of benches determine the overall open cast width. Assuming that four benches are mined a bench width of 40 m seems to be optimal. This bench width is sufficient mining in large scale, but keeps the overall opened mining area small. In parallel mining the benches move parallel to each other without changing their width and layout. This cannot be realized in pivot mining without further ado. If the benches would be turned regularly, the bench width would have to be increased continuously from pivot point towards the outer open cast border. Such a procedure cannot be recommended for bench lengths of 1,500 m and more, as we find them at the El Lajjun open cast. It is more suitable to divide the open cast area into pivot segments and to operate each segment by the parallel method. For that the benches have to be shortened depending on the actual open cast position. After having mined the entire segment the benches are aligned in order to start the next segment. This procedure is shown in fig. 3.12 exemplary for one bench at a length of 2.0 m and a width of 40 m. In this example the first strip of each segment starts in a distance of about 225 m from the theoretical pivot point and runs towards the final slope of the open cast. After having mined the first strip the cut of the next strip is started in a distance of some 300 m further away than the first one. Each strip begins with a 75 long cut whilst the bench is widened from 30 m up to the normal width of 40 m. One segment consists of six strips of 1,775 to 275 m length. The segment covers an open cast area of 265,000 m^2 236,000 m^2 of which can be operated by means of pare mining. About 24,000 m^2 have to be mined in a different way in order to align the final segment position. That is to say that some 90 % of the segment can be exploited by normal operation. Only 10 % have to be mined by residual mining. Each mining segment turns the open-cast position by an angle of 7°5'.