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К ВОПРОСУ О КЛАССИФИКАЦИИ СПОСОБОВ И СХЕМ ВСКРЫТИЯ КАРЬЕРНЫХ ПОЛЕЙ

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вскрытие, система открытой разработки, способ вскрытия, схема вскрытия, карьерное поле, система вскрытия, вскрывающие открытые горные выработки

Аннотация.
Вскрытие рабочих горизонтов при открытой разработке осуществляется в первую очередь с целью создания условий для выдачи добываемого полезного ископаемого. Но добычные работы сопровождаются, как правило, удалением значительных объемов пустых пород. Перемещение этих объемов к месту складирования также обеспечивается соответствующим вскрытием.
Поэтому в деятельности карьера вскрытие рабочих горизонтов играет важную роль и оказывает существенное влияние на технико-экономические показатели предприятия.
Выбор рациональных вариантов вскрытия осуществляется рассмотрением тех или иных сторон данной проблемы: объемов проходческих работ и видов вскрывающих выработок (траншеи, стволы, штольни), глубины заложения внешних траншей, количества горных выработок, места расположения внешних и внутренних траншей, формы трассы внутренних траншей, стационарности вскрывающих выработок, перехода от вскрытия траншеями к подземным выработкам, применения специального оборудования или создания сооружений для перемещения грузов.
Эти и другие вопросы вскрытия рабочих горизонтов при открытой разработке месторождений находятся в центре внимания многих исследователей.
В данной статье выполнено обобщение существующих классификаций способов вскрытия и доказано, что необходимо не расширять классификацию способов, а разделять их на способы и схемы. Приведены примеры схем вскрытия реальных карьерных полей.

ON THE ISSUE OF CLASSIFICATION OF METHODS AND SCHEMES OF QUARRY FIELDS OPENING

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Abstract.
Opening-up (or opening) of working benches at opencast mining is carried out first of all for the purpose of creation of conditions for the output of extracted mineral resources. However, mining operations are usually accompanied by removal of significant volumes of waste rock. These volumes are also moved to the storage site by means of a corresponding opening-up.

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This is why opening-up of working benches plays an important role in the open pit operations and has a significant impact on the technical and economic performance of the enterprise.
The choice of rational variants of opening-up is carried out by consideration of this or that party of the given problem: volumes of mining works and kinds of opening workings out (trenches, shafts, adits), depth of laying of external trenches, quantity of mine workings, locations of external and internal trenches, forms of a route of internal trenches, stationarity of opening workings, transition from opening by trenches to underground workings out, application of the special equipment or creation of constructions for moving of cargoes.
These and other issues of working benches opening-up in the course of open pit mining are in the focus of attention of many researchers.
This article summarizes the existing classifications of methods of opening and proves that it is necessary not to extend the classification of methods, but to divide them into methods and schemes. Examples of schemes for opening real quarry fields are given.

Introduction. Review of the current state on the issue

A review of literature sources, design developments and scientific papers on the issues of quarry fields opening-up shows that individual issues of opening-up were considered depending on the conditions of mining operations in the quarry, the types of transport used, the parameters of the quarry field, the direction of freight flows and capacity of the enterprise, social and environmental requirements [1-16].

A number of works are devoted to a complex study of opening-up operations in relation to specific mining conditions [17-24].

Scientists such as Anistratov, Arsentyev, Khokhryakov, Vinitsky and many others considered the problems of opening-up and related issues of forming freight flows of working benches.

The leading place in solving the problems of opening-up belongs to professor E.F. Sheshko, who laid the foundations of the theory of opencast mining [10, 25, 26].

In his works, the concepts of opening-up of deposits are given, which was understood to be the creation of permanent trenches that open access from the ground surface to the deposit or from its any part to the other, undeveloped part and provide an opportunity to make the cut trenches.

The purpose of the opening-up of deposits, according to Sheshko, is to establish a cargo traffic between the benches of its development and technical constructions on the surface and in the pit. Classification of methods of opening-up and opening mine workings, and also classification of systems of surface mining is offered, in which basis the direction of moving of overburden rock in a quarry is put.

Subsequent development of mining, scientific developments have expanded the concept of opening-up of quarries, introduced new technological solutions.

In the work of Academician N.V. Melnikov [27] it is noted that opening-up of the quarry field includes a set of works on carrying out of permanent mine workings, creation of system of constructions and transport communications providing reliable, cost-effective and safe transport communications of working benches with receiving locations of rock mass and auxiliary objects on an industrial site. Opening-up schemes of a quarry field are characterized by the method of opening, i.e. the type of permanent mine workings used.

Noting the scientific and practical importance of E.F. Sheshko's classification of opening-up methods, N.V. Melnikov proposed his own version of the classification.

The choice of opening-up schemes of quarries, according to Melnikov, depends on various factors. In each specific case, for this purpose, technical and economic analysis of competing options for opening-up should be carried out, with strict consideration of their relationship with the used systems of surface mining. It is proposed to classify the systems of surface mining, which is based on the method of transportation of overburden to the dump.

Academician V.V. Rzhevsky [28] believes that when choosing a method of opening-up the most important are: the surface topography, the size of the quarry in a plan and its depth, the freight turnover of the quarry, the elements of bedding (ore bodies settings), the spatial location of minerals grade, the volume of permanent mine workings and first workings, the schedule of coal preparation and development of deposit at different benches, the method of transportation of rock mass, indicators of the use of mining and transportation equipment during exploitation period and other factors.

V.V. Rzhevsky offered a new classification of methods of quarry opening-up and systems of surface mining. It is noted that each method of opening-up is typical for certain conditions and systems of mining.

Professor A.I. Arsentyev notes that the carrying of mine workings and construction of structures to provide transport links in the quarry associated with the opening [29].

Under the opening of the deposit, according to Arsentiev, refers to the conduct of mine workings (or construction of approaches), opening transport access from the surface of the ground (or industrial site of the quarry) to the deposit or from one part of the mine to another undeveloped and providing an opportunity to prepare the front of the work. A new classification of opening methods is proposed.

Professor M.G. Novozhilov [17] confirms that the essence of the opening of the deposit (quarry field) in opencast mining is to establish a cargo transportation connection between the working benches of the quarries with the points of receiving the rock mass on the surface of the earth (dumps, warehouses, processing plants, etc.) by carrying out appropriate mining and permanent excavations. M.G. Novozhilov proposed various classification options for opening methods [3, 17, 30].

The establishment of a rational method of opening the pit field, Novozhilov emphasized, is one of the most difficult tasks, the technical and economic performance of the mining enterprise depends on the correctness of its solution. The choice of a method of opening is influenced by many factors: surface topography, degree of exploration and conditions of deposit occurrence, production and technical conditions of deposit development, etc.

M.G. Novozhilov, together with V.I. Prokopenko, proposes a method of justifying the economic efficiency of the deposit opening method by the sum of the reduced construction and operating costs [17].

As a result of these studies, as well as in the works of the authors listed above, solutions were found for many aspects of the problem under consideration. However, there is still no consensus on the essence of quarry opening methods, which leads to the creation of their numerous classifications. There is no clear link between the freight flow of the quarry and the opening of its working benches, a step-by-step approach to the solution of the quarry opening, and the relationship between the opening of the quarry and the solution of environmental problems; there is no generalizing methodology for choosing a rational option for opening at opencast mining.

Taking into account the primary importance in the choice of opening the quarry to establish the essence of methods and schemes of opening, consider how to solve the issue of classification of methods of opening at the present time.

Unfortunately, there is no clear definition of what is a method of opening, so the existing classifications have a different approach to this issue.

Common to all classifications is the type of opening workings (inclined or steep trenches, shafts, adits, tunnels).

Along with the general features of opencast mining, there is a distinction between external and internal trenching, flank and central location of opening workings, forms of internal trench routes and other features.

The authors of the classification of opening methods tried to reflect all this diversity with the help of various features.

In the work of A.P. Zotov [31] the methods include opening with horizontal trenches, straight sloping trenches, spiral sloping trenches, dead-end rides, inclined or vertical shaft with crosscuts, adits.

In the works of P.E. Zurkov [32, 33] it is noted that the main features of the classification of opening methods are the presence and type of opening workings, which can be divided as follows:

- the first method is trenching;
- the second method – trenchless opening;

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- the third method – underground mine opening;
- the fourth method – combined opening.

Other features are auxiliary and necessary only for internal division of each method into groups. According to this, the following classification of trenching opening methods is offered:

A. Opening by plain trenches.
I. Out-quarry opening:
1) single trench opening by central or flank trenches;
2) two-trench opening by central-pair, flank or diagonal trenches.
II. In-quarry opening:
1) Single trench opening by dead-end, spiral, loop, combined inclined or steep trenches (inclined elevators);
2) Two-trench opening by pair loop trenches, pair inclined elevators (isolated or interchangeable).
III. Mixed plain opening:
1) Combination of single trench out- and in-quarry opening;
2) combination of two-trench out- and in-quarry opening.

B. Opening by the highland trenches.
I. Out-quarry field opening:
1) Bench opening with separate flank trenches;
2) Bench trenching by common trenches – dead-end or loop.
II. In-quarry ore opening:
1) dead-end;
2) spiral;
3) looped trenches;
4) inclines.
III. Mixed highland opening:
A combination of field and ore opening of highland deposits.

C. Highland and plain trench opening.

In the works of E.F. Sheshko [10, 25, 26] the methods of opening of deposits are classified based on presence, position, quantity and purpose of permanent mine workings as transport communications (Table 1).

Table 1. Classification of Opening Methods by E.F. Sheshko

Name of methods	The essence of methods of opening
1. Opening by separate trenches	Each bench is opened in an independent trench
2. Opening by group trenches	Groups of benches are opened by dependent trenches, different groups of benches are opened independently of each other
3. Opening by common trenches	All benches are opened in one common trench system
4. Opening in paired trenches	Methods 1, 2, 3 with two trenches to open each bench, several or all benches of the quarry
5. Trenchless opening	Opening without permanent tranches
6. Opening by underground workings	Opening when permanent trenches are replaced by underground workings
7. Combined Opening	Opening performed by two or more main methods 1-6

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Besides, E.F. Sheshko offers classification of permanent tranches by their main features (Table 2). Graphic representation of trenches in this table is shown in Fig. 1.

As seen in Fig. 1a, the external trench has two sides, whose location is permanent, and the internal trench has one side, which may be permanent or variable.

Depending on the number of benches, served by trenches with a unified transport communication, separate, group and common trenches are distinguished (Fig. 1b, c, d).

On the working bench, opened by one trench, most often pendulum traffic of dump trucks is used, and the trench is called single (fig. 1e).

If the working bench is opened by two workings, one of which serves for feeding of empty transport to the face and the other – for delivery of loaded transport, it provides through traffic of trucks, and such trenches are called paired (Fig. 1f).

Table 2. Classification of trenches by E.F. Sheshko

Classification features	Basis for classification	Name of trench
Location of trenches relative to the contour of the pit	Outside the contour of the pit	external
	Inside quarry	internal
Number of served benches	Only one bench	separate
	Several quarry benches	group
	All quarry benches	common
Main purpose	For emptying and cargo delivery	single
	For empty delivery only or for cargo delivery only	paired
Stationarity	Permanent location	stationary
	Temporary location	sliding

In accordance with these attributes of trench separation V.V. Rzhevsky proposes the following classification of the main methods of opening (Table 3) [28, 34].

Table 3. Classification of opening methods by V.V. Rzhevsky

The attribute of the method of opening	Methods of opening by		
	Open mine workings (trenches)	Underground workings	Combination of open and underground mine workings
Location of opening workings relative to the contour of the quarry	External, internal or mixed	External, internal or mixed	External, internal or mixed
Stationarity of workings	Stationary, semi-stationary and temporary (sliding) trenches and semi-trenches	Stationary	Stationary or a combination of stationary and semi-stationary (temporary)
Gradient of workings	Steep or inclined trenches and semi-trenches	Vertical, steep or inclined	A combination of vertical, steep and inclined
Number of served benches	Single, group and common trenches and semi-trenches	Single, group and common	Single, group and common
Character of the movement of vehicles at the bench (in-line or pendulum)	Single or paired trenches and semi-trenches	Single or paired	Single or paired

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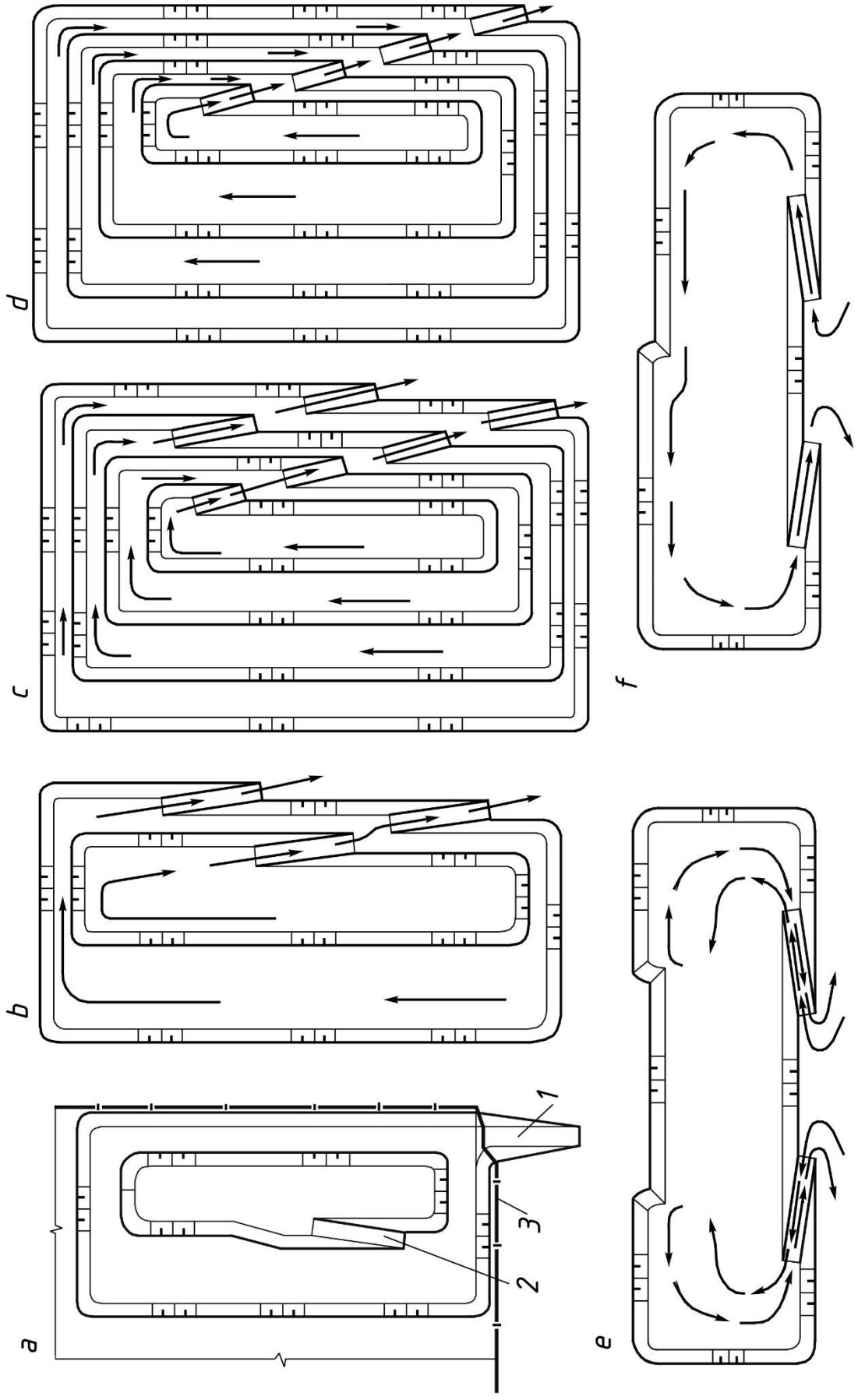

Fig. 1. Schemes of opening the working benches of an open pit with trenches:
a – external (1) and internal (2); b – separate; c – group; d – common; e – single; f – paired; 3 – quarry boundaries

Opening by the common permanent external trenches is used when there are 2-3 benches to be opened and there is no need to dispense freight flows.

The desire for a more complete representation of all sides of the opening of quarries, which are not reflected in the classification of methods, has led to consideration of the relationship of this process with mining development systems.

Academician V.V. Rzhevsky [28] notes that the most common opening methods for various mining development systems are as follows (Table 4):

Table 4. Interrelation of mining development systems and quarry opening methods

Name of mining development systems based on the principle of waste rock moving	Method of opening the benches	
	Stripping	Winning
With direct excavator handling of overburden	Trenchless	Paired or separate external trenches
With multiple excavator handling of overburden	Trenchless	Paired or separate external trenches
With coalface spreaders	Trenchless	Paired or separate external trenches
With the haulage of rocks to internal dumps	Separate or paired internal trenches	Group or separate external trenches
With the haulage of rocks to external dumps	Common, group internal and external trenches, sometimes underground workings	
With the haulage of rock to external and internal dumps	Separate or group trenches of external and internal laying	
Combined with partial haulage of rock	Trenchless method and separate internal or external trenches	Separate external trenches
Combined with partial handling of rock	Separate or group external trenches and trenchless method	Group or separate external and internal trenches

The classification of E.F. Sheshko was developed in the works of N.V. Melnikov [27, 35].

The new classification (Table 5) is based on the division of opening workings into types, their presence, location and purpose.

In his works, S.M. Shorokhov, considering the development of placer deposits by open-cut method, suggests the division of the methods of opening at scraper-and-bulldozer, excavator-and-transport, hydraulic and dredge development [36, 37].

In scraper-and-bulldozer mining method is distinguished by the following methods of placer opening:

1) a continuous transport incline;
2) separate transport incline;
3) foundation pit;
4) without excavation;
5) independent opening of two benches;
6) independent opening of three benches;
7) combined methods of opening.

In case of excavator-and-transport method of mining is distinguished: 1) an independent method of placer opening; 2) an independent method of opening two benches; 3) without excavation; 4) by foundation pits.

In hydraulic placer mining method, the following methods of opening are used: 1) remote trench; 2) mine adit; 3) foundation pit; 4) side opening; 5) trench and foundation pit; 6) independent opening; 7) mixed opening methods.

In case of dredge mining method, the following methods are distinguished: 1) excavation; 2) dams and coffer-dams; 3) mixed opening methods.

A.I. Arsentyev [29], based on useful recommendations of previous authors, offers the following classification of opening methods (Table 6).

Table 5. Classification of opening methods by N.V. Melnikov

Opening scheme	Opening method	Location of workings	Purpose of workings	Served freight flows
Open mine workings	External trenches	Flank Central Mixed	For one bench (separate trenches) For multiple benches (group trenches) For all benches (common trenches)	Removal of rock mass, supply of empty transport vehicles and delivery of materials. Only the removal of rock mass and only the supply of empty transport vehicles and delivery of materials
	Internal trenches	At non-working flank At working flank At quarry perimeter Mixed		
Underground workings	Vertical shafts with crosscuts	Flank Central Mixed	To work off all of the reserves To work off part of the reserves	Overburden delivery Mineral resources delivery Materials delivery Mixed freight flows
	Inclined shafts with crosscuts	Flank Central Mixed		
	Adits with ore chutes	Central		
Without workings (special)	Mining machines and constructions	–	To work off all the reserves To work off part of the reserves	Overburden delivery Mineral resources delivery Materials delivery Mixed freight flows
Combined	Any combination of opening schemes			

Table 6. Classification of opening methods by A.I. Arsentyev

Opening	Opening methods	Additional attributes
Opencast mine workings	Separate trenches (semi-trenches) By the system of advancing (spiral) trenches (semi-trenches) The system of dead-end (loop) trenches (semi-trenches) Foundation pits Combination of opencast mine workings	Internal External Permanent Temporary
Underground workings	Adits (tunnels) with ore chutes Horizontal adits (tunnels) Inclined tunnels Vertical mine shafts Inclined shafts Combination of underground mine workings	Internal External Permanent Temporary

Opening	Opening methods	Additional attributes
Earthwork structures	Dams Cofferdams Embankments Channels The combination of the earthwork structures	Internal External Permanent Temporary
Hoisting equipment	Cable cranes Tower excavators	Internal External Permanent Temporary
Combined	A combination of opencast, underground mine workings, earthworks structures and hoisting equipment	–

In [17], M.G. Novozhilov offers his classification based on several features: the presence, position, number and purpose of opening mine workings as transport communications (Table 7).

Table 7. Classification of opening methods by M.G. Novozhilov

Class of opening	Method of opening	Opening workings
I. Inclined trenches	External trenches	Separate trenches of simple shape Group trenches of simple shape Common trenches of simple shape Pair trenches of simple shape
	Internal trenches	Separate trenches of simple shape Group trenches of simple shape Common trenches of dead-end, loop and spiral shape Pair trenches of different shape Special (auxiliary) trenches
	Combined trenches	Different combinations of the main methods of opening with inclined trenches
II. Steep trenches	Internal steep trenches	Common trenches with conveyor elevators Common trenches with rope tow elevators (skip, cage, car, etc.).
III. Underground workings	Mine shafts and ore chutes	Inclined and vertical shafts Vertical and inclined ore chutes and combinations with mine adits during opening of highland deposits
IV. Combined opening	Combined opening by inclined and steep trenches Combination of trench opening with underground opening A combination of several opening methods	Opening of overburden benches by inclined trenches; opening of winning benches by steep trenches Opening of overburden benches by inclined trenches; opening of winning benches by mine shafts Different combinations of opening methods of classes I and III

The features suggested by E.F. Sheshko are also accepted in the classification of N.A. Kuleshov [38, 39] with a number of specifications (Table 8).

Table 8. Classification of Opening Methods by N.A. Kuleshov

Types of opening workings	Group	Opening method
Permanent trenches	External trenches	Separate trenches Group trenches Common trenches Pair trenches
	Internal trenches	Separate trenches Group trenches Common trenches Pair trenches Steep trenches
	Combined trenches	Different combinations of basic methods
Underground workings	Horizontal workings	Adits Tunnels
	Mine shafts	Inclined mine shafts Vertical mine shafts
Trenchless opening	–	No opening workings
Combined opening	Combination of trench and trenchless opening	Trenchless opening of overburden benches and trench opening of winning benches Trench opening of overburden benches and trenchless opening of winning benches Trench opening of overburden benches and mine shafts opening of winning behches

In the work of V.S. Khokhryakov [40] it is considered that the following classification of methods of opening is more simple:

1. Opening by inclined trenches with a simple form of the route.
2. Opening by steep trenches.
3. Opening by spiral ramps.
4. Opening by loop ramps.
5. Opening by dead-end ramps.
6. Trenchless opening.
7. An opening on a sloping hillside.
8. Opening by underground workings.
9. Combined opening.

However, in another paper [41], V.S. Khokhryakov offers a more detailed classification of opening methods (Table 9), where the first classification feature is the design of the opening mine, its spatial position relative to the final contour of the pit.

V.S. Khokhryakov gives the definition of an opening [41], which means mining and construction work to create a complex of permanent and temporary trenches and ramps in the open pit, as well as other mining workings and constructions that provide freight transport connection between the working benches and receiving points on the surface.

Table 9. Classification of Opening Methods by V.S. Khokhryakov

Group of opening methods	Main classification attributes				Rational application conditions
	Location of workings relative to the contour of the quarry and design of workings	Route shape	Stationarity of mine workings	Number of mine workings and their location	
A	External trenches	Straight	Permanent and temporary	One central, one or two flanks	Shallow quarry depth, upper benches of deep quarries
B	External semi-trenches	Straight	Permanent or less often temporary	One or two flanks	Mountainous landscape, upper group of benches
		Loop Dead-end	Permanent		Deposits on a hillside
C	Internal trenches	Straight	Permanent or sliding	One or several	Shallow quarries, separate quarry benches
		Dead-end			Quarries of medium and large depths, railway transport
		Spiral	Permanent and temporary	At all pit edges	Quarries of medium and large depths
D	External steep trenches	Straight or zigzag-shaped	Permanent or less often temporary	One or several flank or central	Opening of deposits located on hillsides to relocate the mined rock
	Internal steep trenches				Opening of deep quarries for lifting of mined rock by skips and conveyors
E	Underground shafts, ore chutes, tunnels, adits	Vertical, inclined, horizontal	Permanent and temporary	Central and flank	Mountainous landscape (for relocating the mined rock) and deep quarries

It is noted in [42] that different natural conditions of mineral deposits and different equipment used allow for different methods of opening the quarry fields. That is why J.V. Bunin suggests classifying these methods by the presence, position, quantity, purpose and type of opening workings (Table 10).

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Table 10. Classification of Opening Methods by J.V. Bunin

Class of opening	Classification attributes		
	Presence and type of opening workings	Location of opening workings	Quantity and purpose of opening workings
I	Permanent trenches	External	Separate Group Paired Common
		Internal	Separate Group Paired Common Steep
		Mixed	Different combinations of basic methods
II	Underground mine workings	Horizontal	Adits Tunnels
		Mine shafts	Vertical Inclined
III	Trenchless opening	No mining workings	Opening without carrying of opening workings
IV	Combined opening methods	Combination of trench and trenchless opening and with opening by underground mine workings	Бестраншейное вскрытие Trenchless opening of overburden benches and trench opening of winning benches Trench opening of overburden benches and trenchless opening of winning benches Trench opening of overburden benches and underground workings opening of winning benches

In [43], the chapter "Development of Opening Methods of Quarries and Classification of Surface Mining Systems" is devoted to this issue, where it is proposed to separate opening methods with allocation of classes, groups and methods (Table 11).

In the opinion of the author Yu.S. Razmyslov, such a division significantly clarifies and expands the classification of opening methods, taking into account modern requirements of opencast mining practice.

In the same paper it is proposed a new definition of opening the quarry field, which is understood as a system of mine workings (open, underground), which in combination with transportation equipment ensure the development of working benches of the quarry and their freight transport connection with constructions on the surface, as well as among themselves.

Table 11. Classification of opening methods by Y.S. Razmyslov

Class		Group		Method	
Index	In terms of the presence and type of opening workings	Index	In terms of the location of the workings in the spatial plane	Index	In terms of the quantity of opening benches and of the purpose of working
I	Trench opening	1	Inclined external trenches	a	Separate
				b	Group
				c	Common
				d	Paired
		2	Inclined internal (permanent) trenches	a	Separate
				b	Group
				c	Common (dead-end, loop, spiral)
				d	Paired
		3	Inclined internal (sliding) trenches	a	Separate
				b	Group
				c	Common (dead-end, loop, spiral)
				d	Paired
		4	Steep trenches	a	Separate
				b	Group
				c	Common
		5	Inclined external semi-trenches	a	Separate
				b	Common (dead-end, loop)
				c	Group
II	Underground mine workings opening	1	Vertical shafts	a b c	Separate Group Common
		2	Inclined shafts (crosscuts)		
		3	Adits		
III	Opening without mine workings	–	–	–	–
IV	Combined opening	1	Combination of trench opening groups	n	The number of methods is determined by the combination of methods a, b, c, d from groups 1, 2, 3, 4 of class I
		2	Combination of trench opening with underground mine workings opening	n	The number of methods is determined by the combination of methods a, b, c, d from groups 1, 2, 3, 4 of classes I and II
		3	Combination of trench opening and opening without mine workings	n	The number of methods is determined by the combination of methods a, b, c, d from groups 1, 4 of classes I and III
		4	Combination of several groups of opening classes	n	The number of methods is determined by the combination of the appropriate groups and classes

Considering systems of surface mining, the author marks that the way of moving of overburden to the dumps which is an integral attribute of classifications of surface mining systems, represents a problem of a cargo-transport order to which opening of quarry fields is subordinated also. On the basis of it the conclusion is drawn that creation of a certain minimum of schemes of technological interrelation of methods of opening of quarry fields and mining systems for difficult conditions of open-cast mines of the future will be the valuable contribution to the theory of designing of open-cast mines.

Conceptual approach to the terms "method of opening" and "scheme of opening" and their definition

The analysis of considered classifications of opening methods shows that the majority of them are based on several features: presence and type of opening workings (trenches, underground workings, trenchless opening, combined opening), and also number of benches opened by each trench (separate, group, common); trench profile (full, semi-trench); trench location relative to the pit contour (external, internal, mixed) and type of underground workings (horizontal, inclined, vertical). As to such signs as stationarity of trenches, form of routes, movement on trenches of vehicles, they at allocation of methods of opening are partially considered in some classifications.

Authors of the considered classifications aspired to reflect all versatility of a question in one concept – a method of opening. Only Academician N.V. Melnikov considers the interdependency of the notions of the scheme and the method of opening, but even here, there is no provision, what lies at the heart of each of them. The classifications considered are characterized by cumbersomeness and they lose the meaning of the method itself.

The variety of approaches to the classification of opening methods, in our opinion, is explained by the fact that due to the withdrawal of mining operations of many ore and, recently, coal pits, to a greater depth, it is increasingly necessary to solve some or other issues of opening, which in fact do not reflect any of the existing methods. Hence, the desire either to miss some signs and introduce others, or to leave the old ones and introduce additional ones, which leads to even more cumbersome classifications, which, however, do not fully reflect the technological essence of opening. Secondly, the difficulty of displaying all sides of the opening by one classification is explained by the variety of conditions for the application of open-cast mining (different angles of formation dip, the surface topography, the structure of the deposit, the type of transport). Each of these conditions has its own features of opening.

So, for example, at development of shallow horizontal deposits their opening is carried out by systems of trenches of external laying on which is transported, as a rule, only a mineral. The main tasks here are minimization of trench volumes and organization of joint work of stripping and winning equipment.

When developing steep-falling deposits, significant volumes of overburden must be transported from great depths to external dumps. There are such problems as stationarity of mine workings, the shape of the route, the number of stripping workings and other, fundamentally different from the previous.

All this suggests that it is impossible in one concept of "method of opening" to collect all the signs of a multilateral issue, which, along with the method should also have a concept of "scheme of opening", which takes on some signs. These uncertainties make it difficult to establish what exactly should be the subject of consideration for the choice of opening options.

The desire to reflect the main features of an opening in terminology suggests that the concepts of "method of opening" and "scheme of opening" should be separated. This was noted in the discussion on improving the terminology of the mining industry, which was held back in the 70s of last century in the famous journal "Coal" [44-46].

In the course of this discussion, many authors of articles and notes came to the following opinion: "the division of concepts related to the set of mine workings into a 'scheme' and 'method' is not only lawful, but also necessary, most correctly reflecting not only the inner essence (content), but also the type (form) of the process described" [46].

The separation of these concepts is also observed in the academic literature, but there is no unity in the definition of "method" and "scheme".

Academician V.V. Rzhevsky [34] notes that the method of opening is determined by a number of features, first of all by the type of opening workings, and then offers concepts:

- the scheme of opening routes is a set of routes of all opening workings providing at the given period of time a freight traffic connection of working horizons of the open pit with structures for receiving and re-handling of mined rock in the open pit and on the surface;
- the scheme of opening is characterized by the type, number and spatial position of routes of opening workings at a certain position of mining operations, or, in other words, at development of mining operations in any calendar period of construction and operation of the open pit.

Previously, V.V. Rzhevsky [47] defined the scheme of opening as a set of mine workings, earthwork constructions and transport communications, providing connection of working benches of the open pit with constructions for receiving and overloading of mined rock in the open pit and on the surface.

Professor V.S. Khokhryakov [41] gives the following concept: the method of opening is a complex of mine workings and structures in the quarry, characterized by their structure, construction, number, spatial position, dynamism. However, nothing is said about what is the scheme of opening, although this term is encountered in the future when considering the opening of horizontal, flat, inclined and steep deposits, and the proposed concept of the method is more consistent with the scheme of opening, as it describes the spatial position of opening workings.

These uncertainties make it difficult to determine the rational variants of opening, as it is not clear what to take as a subject of calculation - a method or scheme, what factors and signs affect the parameters of opening.

To eliminate this shortcoming, it is proposed to clarify the definitions of the opening itself, as well as its methods and schemes, on the basis of which to establish the subject of study to find a rational variant.

It is proposed not to expand the classification of methods, and divide them into methods and schemes taking into account the fact that the purpose of the opening is to establish a connection between the freight traffic of the working horizons and the places of cargo receiving inside and outside the quarry.

The method of opening is the creation of conditions for moving the freight of working benches of the quarry with the use of open (trench) or underground (mine) workings, as well as with the use of excavation equipment, special structures or constructions (special).

Classification of opening methods by the presence and type of opening workings is given in Table 12.

Table 12. Classification of opening methods

Opening method	The essence of opening method
Trench	Opening by the system of open-pit mine workings
Underground	Opening by the system of underground mine workings
Special	Opening by the system of mining equipment, special structures and constructions
Combined	Opening by a combination of trench and special; trench and underground; underground and special; special, trench and underground methods

As can be seen from the table, each method is an opening system that provides the operation of the freight flows of the quarry benches.

Spatial or graphical representation of the opening system of this or that method of opening in a certain period of quarry operation is called opening scheme.

The essence of the opening process reflects the methods, and its form – schemes.

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The method of opening shows how the working horizons are opened and the scheme shows how the freight is moved in a spatial space by this or that method during a specific period of the quarry operation.

Thus, the essence of the method of opening is expressed through an opening system (Fig. 2).

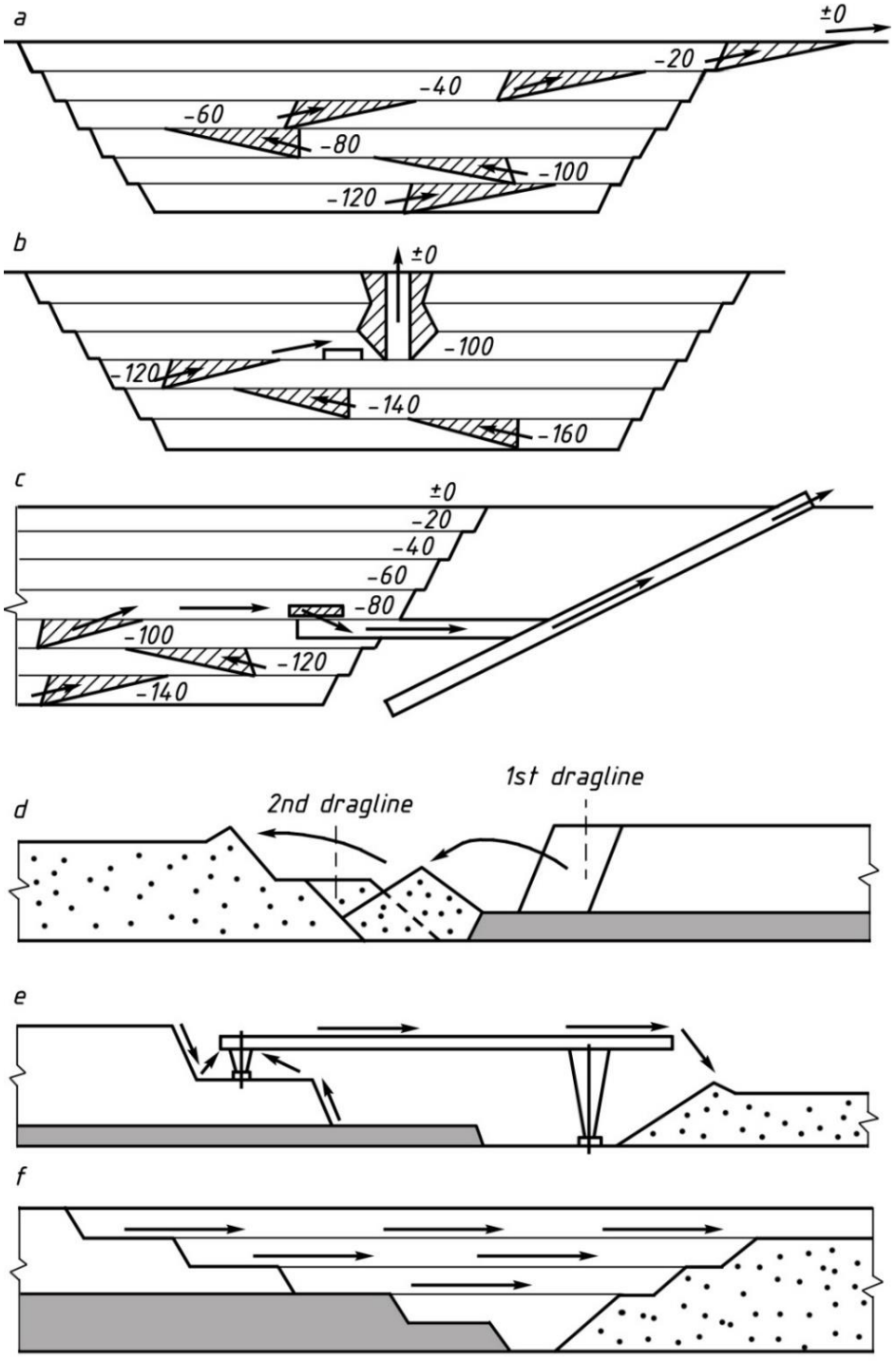

Fig. 2. Opening systems of trench (a, b), trench-underground (c) and special (d, e, f) opening methods

Opening systems at opencast mining operations are sets of:
inclined trenches and semi-trenches, steep trenches (fig. 2a, b, c),

underground mine workings (crosscuts, tunnels, inclined shafts, adits) (fig. 2-c), connected with each other by transport communications and providing conditions for moving coal and rock from the faces to the place of their storage;

excavation machines, carrying out excavation and re-excavation of overburden according to direct dumping scheme (fig. 2.8-d);

excavators in combination with special constructions for belt conveyors, providing mined rock freight flow (fig. 2.8-e);

special constructions (dams, overpasses, embankments, berms) (fig. 2.8-f) to direct the freight flow from the face to the place of freight receiving.

Since the largest volume of freight flows at open-pit mining operations is transport, the most common are trench and underground opening methods and their combinations, represented by systems of opening workings. The spatial position of these workings, taking into account their purpose is a scheme of opening the pit in a specific period of service life of the pit.

Opening of working benches of an open pit by the underground mine method at which moving of cargoes from a face to a place of receiving of a mined rock this or that type of transport is carried out by means of systems of underground mining workings out, is applied most often in a combination to a trench method.

The mine method in its pure form takes place at opening of a mining ledge of horizontal or hollow strata by underground workings under internal dumps.

This method is used to open pits with inclined shafts, adits, ditches, and ore chutes (Figure 3).

As a rule, adits and inclined shafts are intended for conveyer transport. However, the adits can be passed for passing railway or dump trucks. The ore chutes are designed for gravity transport.

Underground mine openings can be classified according to V.V. Rzhevsky's suggestion [18] by the same features as trenches: position relative to final contour of quarry (external or internal); stationarity (stationary, temporary); number of served benches (separate, group, common); purpose (single, pair). Consequently, at open-pit mining operations, opening with the use of underground mine workings also has many options of opening systems.

At open-cast mining of deposits opening of working benches of a quarry by underground mining workings is the most expedient at the combined automobile-conveyor transport for accommodation of conveyor beltings in these mine workings.

Working benches of open-pit mines developing steep and inclined deposits are usually opened by inclined shafts passed outside the open-pit (fig. 3a).

The opening of mining benches of open-pit mines developing horizontal and flat deposits is carried out by horizontal or inclined tunnels, placed under internal dumps (fig. 3b).

Highland deposits can be opened by adits with crosscuts (fig. 3c).

Schemes of different methods of opening

Opening systems have different spatial evolution during different periods of quarry operation depending on the method of opening, types of transport, parameters of mining enterprises and a number of other conditions [48-51].

Thus, the variants of spatial evolution of freight flows of working benches of the quarry are the essence of the scheme of opening and depend on such factors as methods of opening, conditions of open-cast mining operations, development systems, parameters of the quarries, types of transport and others (Table 13).

It gives the reason to offer the following definition: scheme of opening is a description or graphic representation of spatial position of opening systems of this or that method of opening during certain period of opencast operation.

Mutual combination of these factors determines the spatial evolution of freight flows of the working benches of the quarry, which is expressed in the scheme of opening.

Opening schemes are characterized by a number of features:

- ✓ the location of the opening system relative to the quarry contour;

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- ✓ the purpose of the opening system;
- ✓ the number of benches served by the opening system;
- ✓ the stationarity of the opening system;
- ✓ the number of the opening systems;
- ✓ the places of receiving the mined rock;
- ✓ the shape of the route of the opening system.

The scheme of opening is a qualitative characteristic of an open pit in a certain period of time of its operation and reflects parameters of the freight flows corresponding to the assigned production capacity of the enterprise, parameters of opening workings out and parameters of the equipment providing work of these freight flows. Consequently, it is the schemes of this or that method of opening are the object for choosing a rational option.

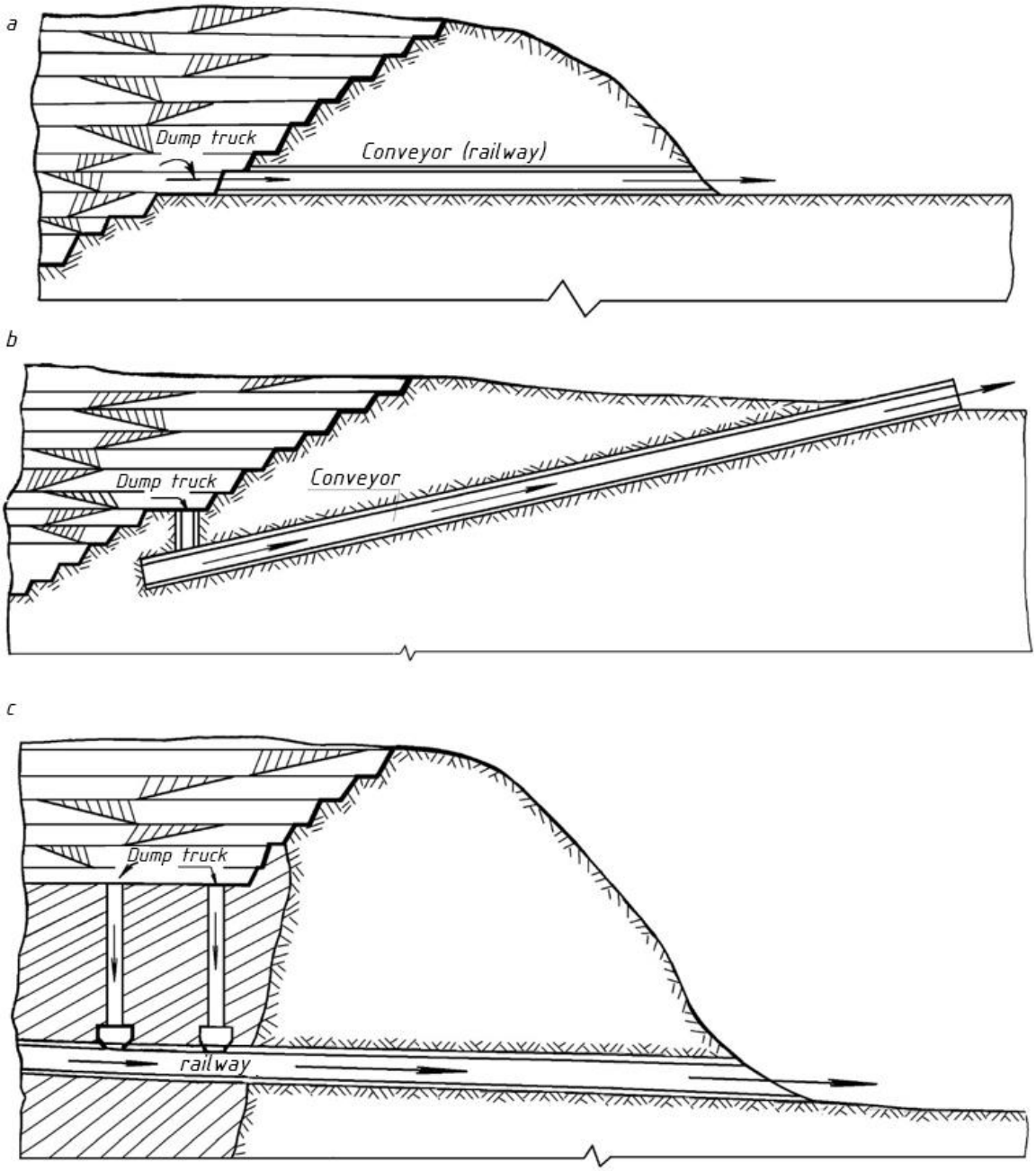

Fig. 3. Schemes of opening of working benches of quarry by adits (a), inclined shaft (b), ore chutes and adits (c) in combination with inclined trenches

The rational scheme of opening is determined, first of all, by the rational way of moving the cargoes of working benches of the quarry to the places of their receiving or storage in accordance with the volumes and direction of freight flows.

Table 13. Factors that determine the scheme of opening up

Factors	Form of expression of factors
1. Technological	
Opening methods	Trench, underground, special, combined;
Mining Development System	longitudinal, transverse;
Quarry Parameters	length, depth, production capacity, stripping ratio;
Operation period of the quarry	commissioning, exploration of planned output, maximum development of the operations;
Direction of freight flows	outside the open pit, into the worked-out space of the open pit;
Movements of loads	locomotives, dump trucks, conveyors, skips, excavators, transport constructions, by pipeline;
Deposit development sequence	without underground works, before underground works, after underground works, together with underground works
2. NATURAL	
Surface topography	flat, mountainous;
Seams bedding	horizontal, flat, inclined, steep;
Massif structure	coalless, coal-bearing
3. ENVIRONMENTAL	
Loss of coal	in the process of seam extraction by an excavator, at intersection of seams by an opening system, at preservation of reserves in the pillars for opening systems;
Earth's surface disturbance	during excavation of external trenches, while push-back the non-working flank of the pit to locate internal stationary trenches.

Dependence of methods and schemes of opening of quarries on parameters of the main freight flows is determined by technical indicators of options, which include such as the number of mining and transport equipment, parameters and volumes of opening workings etc. These indicators are the initial values of economic calculations to select an effective option.

Systematization of the main factors that determine the method and scheme of opening, and independent attributes that characterize the spatial development of freight flows in a particular period of operational work; field observations and studies of tools for excavation, transportation and dumping; systematization of technological schemes and freight flows in the longitudinal and transverse system of the mining front – all this has provided the basis for the development of scientific and methodological principles for calculating the technical parameters of the schemes of opening and economic indicators at substantiation of options for opening of working benches of quarries.

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The analysis of the development of open-pit mining operations, the formation of freight flows in the longitudinal and transverse technologies in relation to the conditions of various deposits shows a great variety of schemes of this or that method of opening, reflecting the shape of the process, as well as all possible methods of opening, reflecting its type (content).

When developing horizontal deposits of the depth type, opening of rock benches is carried out by direct ramps on the relief and draglines that pass the overburden into the mined-out space. Opening of winning benches is carried out by inclined trenches with creation of transport lanes, as a rule, on the bottom of the mined-out seam in the zone of internal dumps.

At working out of flat deposits of a highland-depth type opening of transport benches of a highland part is carried out by direct ramps on a relief or by inclined semi-trenches. Transport benches of a depth part are opened by inclined trenches.

Opening of the rock benches that are worked out according to the transportless (direct dumping) scheme, is carried out by overburden excavators (draglines) themselves. The coal seam at the transportless stripping zone is opened by inclined trenches on a working quarry flank or inclined semi-trenches, passed on seam bottom in a zone of internal dumps.

In the mining of inclined depth-type deposits the working benches are opened with inclined trenches.

Opening of working benches of inclined deposits of a highland-depth type is carried out by direct ramps and cofferdams on benches of a highland part, inclined trenches on benches of a depth part.

At development of steep deposits of depth type opening of working benches is carried out by inclined and steep trenches.

Taking into account the existing experience of opening the working benches of coal and ore quarries, it should be considered the possibility of application on the surface mining of opening underground mine workings in the development of horizontal, flat and inclined depth-type seams and for the highland benches of depth-type deposits.

All this confirms the conclusions that the schemes of opening open pits are based on the main features – ways to create conditions for the operation of freight flows, which are expressed by the presence or absence of mine workings, structures, equipment. Type of opening workings, structures and structures is the basic scheme of opening, depending on the conditions of mining operations.

Relationship of methods and basic schemes of opening, as well as the conditions of their application is presented in Table 14.

Table 14. Relationship of methods and basic schemes of quarry benches opening

<table>
<tr><td colspan="3" rowspan="2">Conditions of application</td><td colspan="4">Methods of quarry benches opening</td></tr>
<tr><td>trench</td><td>underground</td><td>special</td><td>combined</td></tr>
<tr><td colspan="2">Highlands quarry benches</td><td rowspan="5">Basic schemes of opening</td><td>straight inclines, inclined semi-trenches, inclined trenches, steep trenches (ore chutes)</td><td>tunnels, adits with ore chutes</td><td>excavators, rope constructions</td><td rowspan="5">combination of two or three main methods</td></tr>
<tr><td rowspan="4">Deep quarry benches</td><td>horizontal seam</td><td>straight inclines, inclined trenches</td><td rowspan="2">tunnels below internal dumps</td><td rowspan="2">excavators, conveyor systems, embankments, blasting works</td></tr>
<tr><td>flat seam</td><td>inclined trenches</td></tr>
<tr><td>inclined seam</td><td rowspan="2">inclined trenches steep trenches</td><td rowspan="2">shafts with crosscuts</td><td rowspan="2">draglines, embankments</td></tr>
<tr><td>steep seam</td></tr>
</table>

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Methods and schemes for opening up quarry fields with longitudinal technologies

Opening of horizontal deposits has the same direction both in longitudinal and transverse mining systems.

When developing horizontal deposits, it is reasonable to distinguish periods with different parameters of freight flows: construction of the open pit, its commissioning, development of project capacity, maximum development of mining operations.

During construction of the open pit, mining and preparation works are carried out, which create the initial front for stripping and winning operations, as well as the required volume of the mined-out space to accommodate internal dumps. During construction, overburden freight flows are sent to external dumps.

If the overburden thickness is less than the dragline's digging depth, the stripping excavator can also remove minerals and release them to the surface. In this case, there is no need to perform opening workings for the winning horizon.

At high overburden thickness, the mineral is processed by winning excavators and transported to the place of storage through opening workings, which are located on the flank or in the center of the quarry field.

The mining front on horizontal deposits can be located along the length of the pit (longitudinal technology) or its width (transverse technology). In both cases, there will be no principal difference in mining operations.

During the operation of the open pit overburden freight flows are moved by excavation equipment or by means of transport to the mined-out area formed after winning. Freight flows of a mineral are transported to the surface either by stripping excavator (with low thickness of overburden) or from a winning excavator by some type of transport through opening workings.

Opening workings are located on the flanks or in the center of the quarry field, they can be inclined or steep trenches, as well as underground workings. Inclined trenches are used when using wheeled types of transport (railway or dump trucks). When using conveyors to transport minerals, the opening of the winning horizon can be done by steep trenches or underground workings.

Underground mine workings on horizontal deposits can be used for placing in them transport lanes, which are created in the mined-out area for mineral freight flows, and which in open form take away significant capacities from internal dumps.

Thus, when developing horizontal deposits, opening of working benches can be performed by all methods with their different schemes.

Nowadays, flat, inclined and steep deposits are developed, as a rule, using longitudinal technologies.

The longitudinal technology in opencast mining is characterized by consistent development of mining operations along the length of the quarry from the upper benches to the final depth of the opencast mine.

Each downstream bench is put into operation after the corresponding advancement of mining front at all upstream working benches, which makes it possible to open and prepare it.

The development of mining operations with this technology has two main periods of open pit operation:

– The first period includes from a moment of commissioning to the moment when the upper bench reaches the surface boundary of the open pit;

The second period includes the time from the moment of the upper bench reaching the quarry surface boundaries to the moment the mining operations are completed at the final depth of the pit.

The peculiarity of the first period of mining development is the creation of mined-out space, which increases in terms of plan and depth with the commissioning of the next bench and is accompanied by an increase in freight flows of overburden transport.

Mined-out area in the development of flat and inclined beds is formed by a working flank on the side of the hanging wall, a non-working flank on the side of the footwall of the deposit and two non-working ends of the pit.

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When developing steep seams this area in the first period forms two working flanks on the side of the hanging and lying sides of the deposit and two non-working ends of the pit.

The first period's freight flows are characterized by increased volumes of overburden from the start of operation to the maximum development of mining operations. The end of the first period is marked by the maximum volume of current overburden.

In the second period of mining development, the commissioning of the next deep bench is accompanied by a decrease in overburden volumes, as more and more upper benches approach the boundaries of the quarries, and the benches become non-working.

In this connection, the longitudinal technology is characterized by various parameters of freight flows during the construction of the pit, production capacity development and maximum development of mining operations.

Depending on the strata dip angle, each of these periods has its own features.

When developing flat deposits, stripping operations during the construction period of the open pit can be carried out using the direct dumping technology with laying the rock outside the pit on the external dumps. The mineral is taken out by winning excavators and is delivered to the surface by transport through opening workings.

During the operation of the open pit developing the flat strata, part of the overburden over the workable seam is mined out according to the direct dumping (transportless) scheme with its laying in the mined-out area. The rest of the above overburden is worked out according to the transport scheme and moved to external or internal dumps.

Provision of freight flows of transport overburden is carried out by mining workings, which are located on the working flank and on the non-working ends of the pit.

To develop the designed production capacity of the open pit, it is sufficient to develop works on the bench of transportless overburden and winning bench, opening of which is carried out by a system of inclined semi-trenches for dump trucks, passed on the bottom of the seam in the mined-out area.

At the maximum development of mining works opening of transport rock benches is carried out by inclined trenches for railway or dump trucks. With a large number of transport benches it is possible to switch to combined trucks-and-rail transport.

Winning bench with the maximum development of mining operations can be worked out for dump trucks and opened by systems of semi-trenches, passed through the seam bottom in the mined-out space. However, this scheme of opening requires setting the volume of mined-out space, which complicates the placement of rocks in the internal dumps. It is possible to eliminate this drawback by replacement of inclined semi-trenches by inclined trenches on working flank or by system of inclined underground mine workings under internal dumps for dump trucks.

The use of the combined road-conveyor transport with overload at the level of a winning bench for coal freight flows allows to use inclined tunnels under dumps as opening excavations for conveyer beltings.

Inclined and steep seams at longitudinal technology are developed according to transport scheme with direction of overburden and mineral freight flows outside the open pit (Fig. 4).

During construction of the pit, which is developing an inclined deposit, provision of overburden and mineral resources freight flows is made by external inclined trenches, located on flanks of the quarry field, for railway or dump trucks (Fig. 5a).

During the period of development of design production capacity the increasing freight flows of overburden and mineral are directed to the places of their storage by the inclined internal trenches, located on the non-mining flank of the quarry (worked-out seam bottom), and external trenches on the flanks of the quarry field.

During the period of maximum development of mining operations, it is often necessary to switch to combined road-rail or road-conveyor transport. Opening of working benches with a combination of wheeled hauling units is carried out by inclined trenches.

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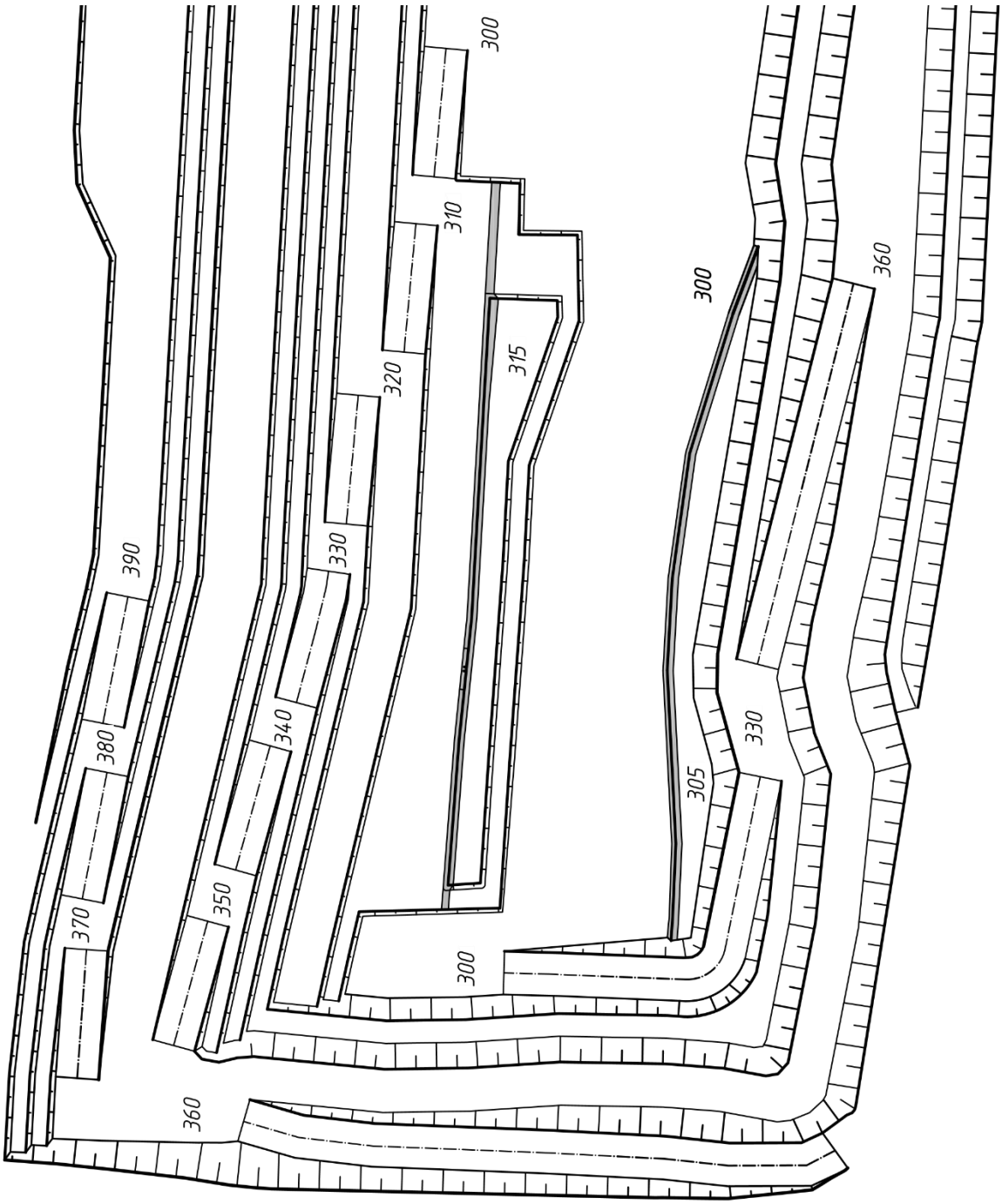

Fig. 4. Scheme of quarry opening by internal inclined trenches

In case of application of automobile-conveyor transport, automobile freight flows from the faces to the dumping station are provided by inclined trenches located on non-working and working flanks of the opencast. For conveyor freight flows it is possible to cut steep trenches on the non-working board or inclined shafts with crosscuts.

Mining and construction works at the development of steep deposits are carried out according to the transport scheme with the removal of overburden and mineral through the external inclined trenches, located on the flanks of the pit, which has two working boards.

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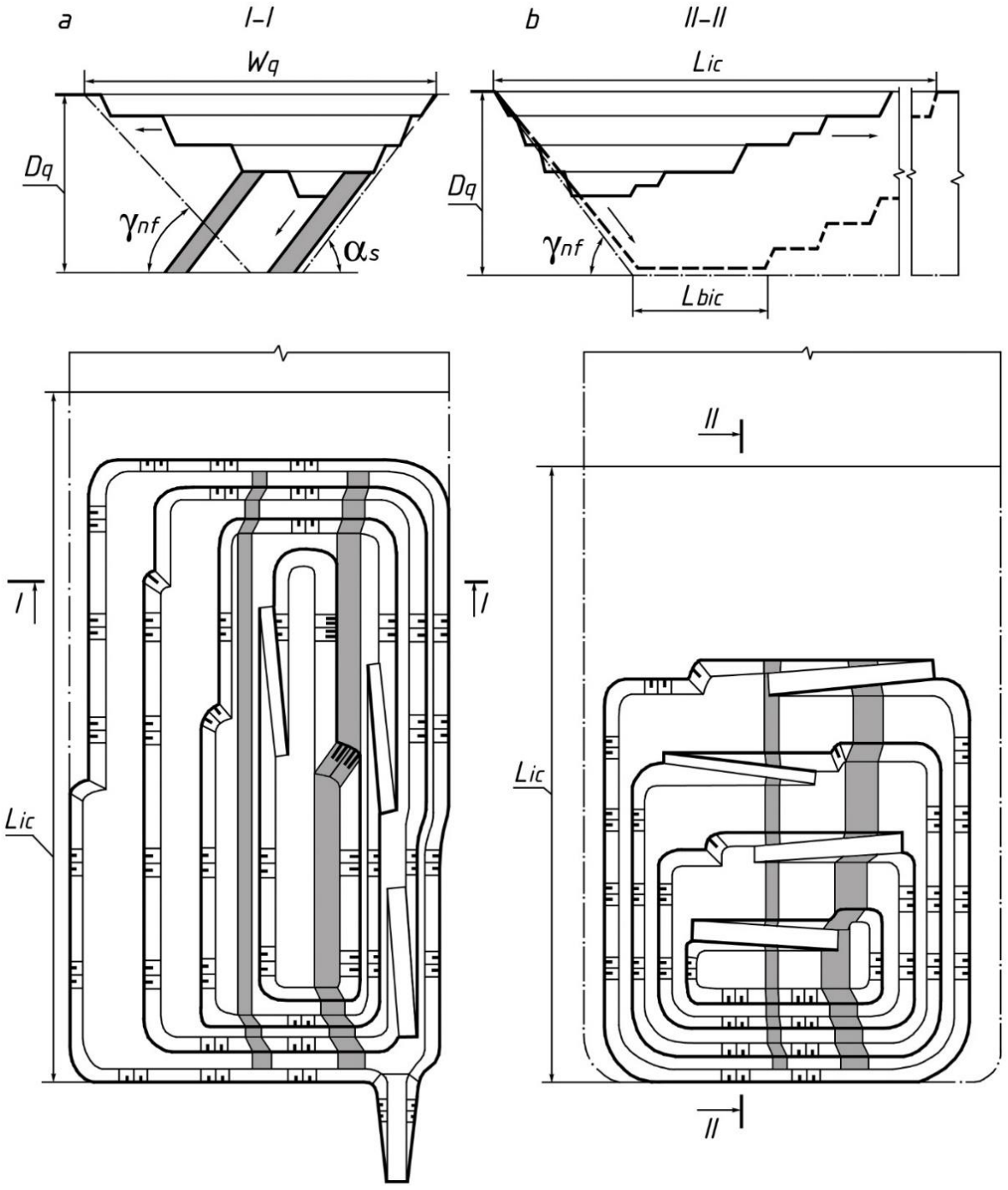

Fig. 5. Opening the working benches of the initial capacity at longitudinal (a) and transverse (b) mining development systems

In the process of development of production capacity it is often necessary to increase the number of systems of opening workings for dispersal of freight flows.

Opening trenching systems include internal trenches located on the working flanks of the pit and external trenches on the flanks of the pit field.

External and internal trenching systems are also used for maximum mining development when combined road-rail transport is used. In Fig. 6 shows the scheme of opening by internal inclined trenches, located on the mining flank. The shape of the route of the opening workings is a loop.

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In case of combined road-conveyor transport, internal trenches located on the working flank of the open pit perform opening of benches worked for dump trucks. For conveyor freight flows it is possible to cut a steep trench, if there is a non-working flank or the end of the pit, or cutting a sloping shaft with crosscuts.

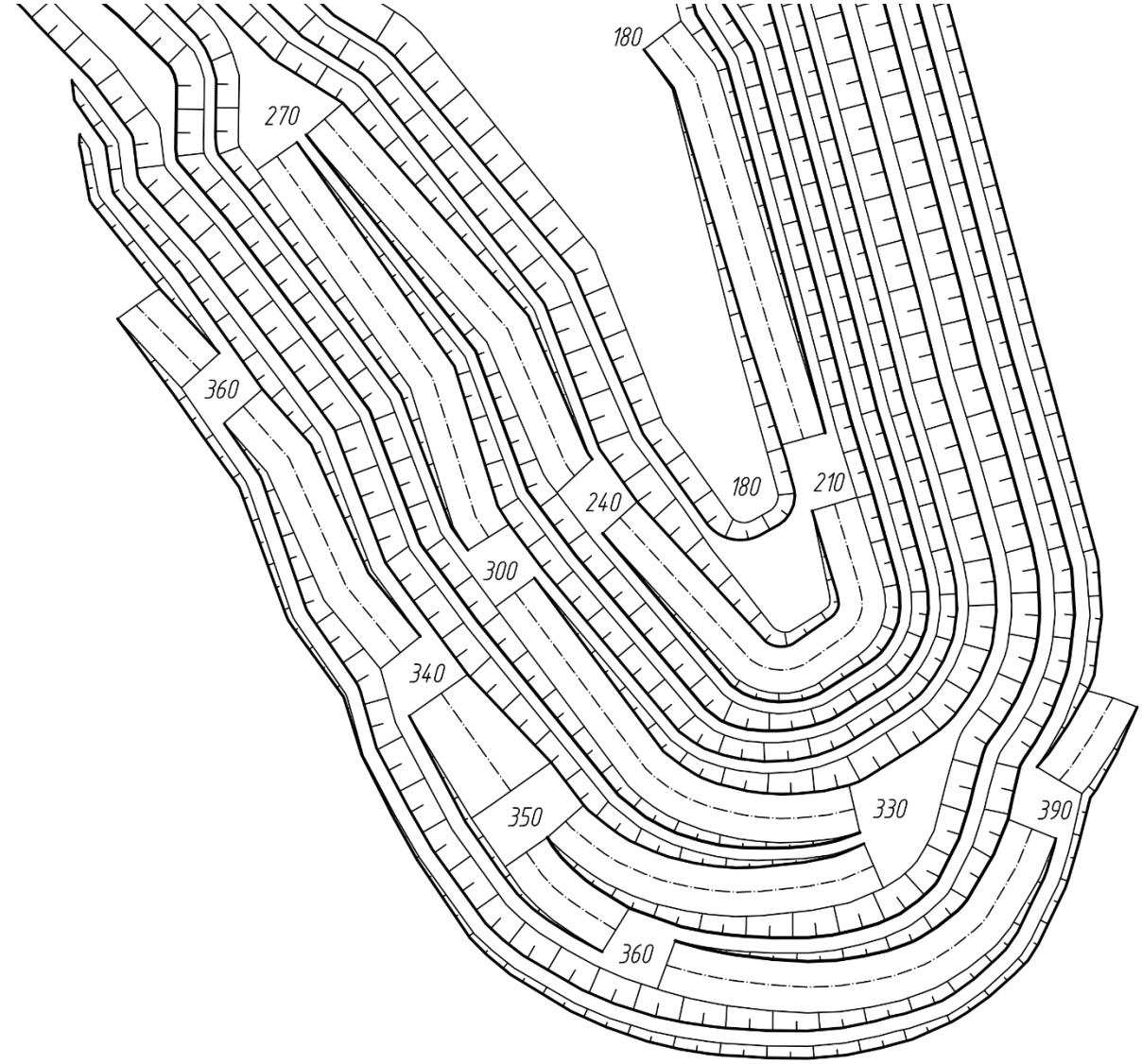

Fig. 6. Scheme of quarry opening by internal inclined trenches, located on the working flank

Methods and schemes for opening up quarry fields with transverse mining systems

The essence of the technological scheme of mining operations at their transverse development remains the same as with longitudinal. Each scheme consists of excavation works, movement and placement of cargo, linked to each other by a freight flow.

Excavation work can be carried out by means of the hydraulic mining, rope shovels, hydraulic shovels and draglines. Excavating works are carried out, as in longitudinal technology, without preliminary loosening or with the use of drilling and blasting operations.

Some peculiarity of excavators' operation arises in the coal-bearing zone of inclined and steep seams. This is due to the fact that the faces in the transverse technology moves cross the strike of coal seams (Fig. 7). In this order of mining operations at the bench there is no division of excavator blocks into rock and coal as in the longitudinal technology. There is no need to make cut trenches along the seams. Excavator faces at the bench alternate between rock and coal.

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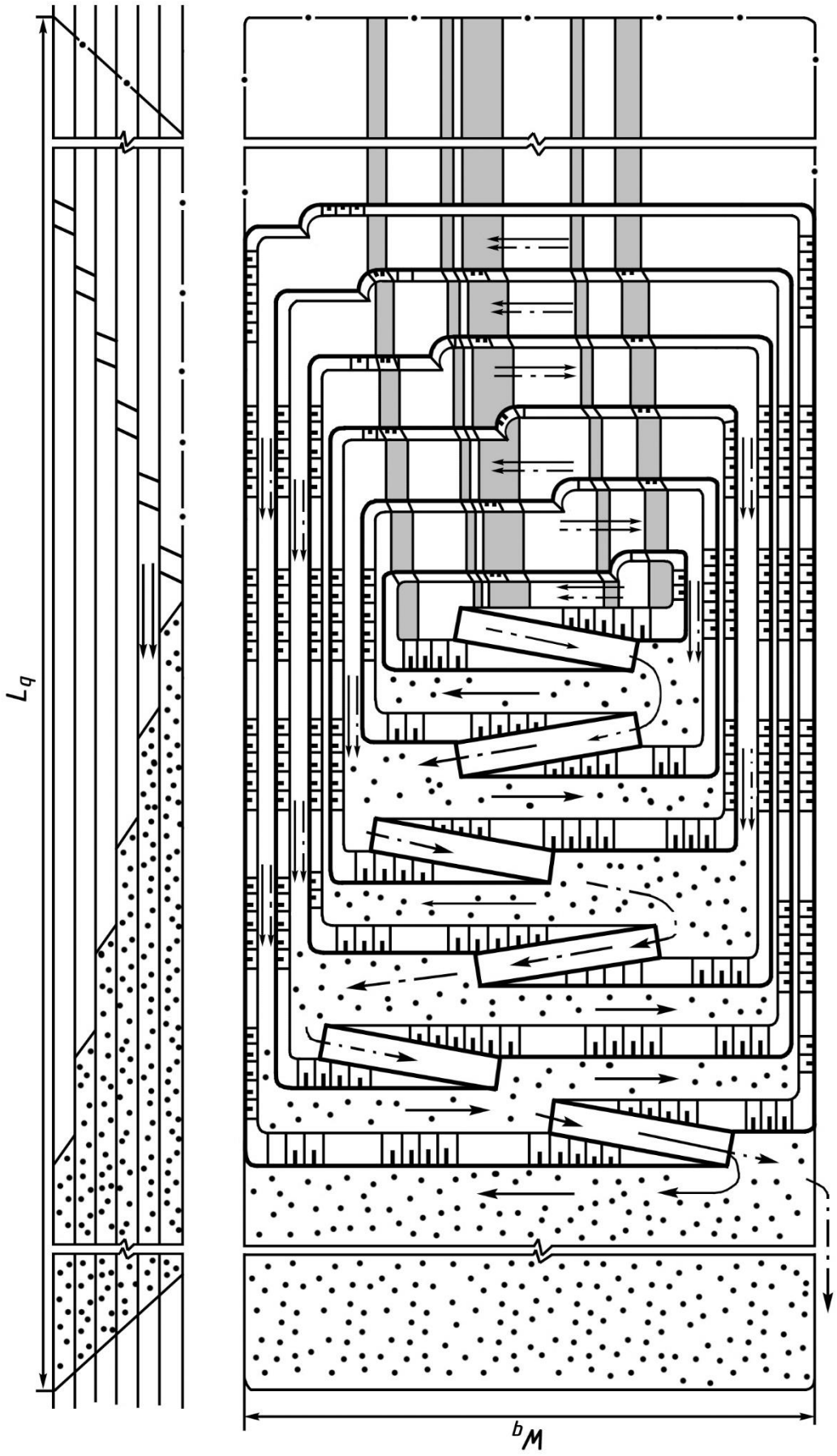

Fig. 7. Opening by trenches located on dump tiers at transverse mining system

When approaching the excavator face to the formation from the hanging wall it is necessary to have such a combination of excavator parameters and the height of the bench, which will provide maximum completeness of a seam scooping with minimal coal losses.

When approaching the excavator face to the layer from the lying wall it is necessary to perform the outpacing stripping works from the hanging wall, then excavate the coal, and then work out the overburden from the lying wall. Extraction of coal should also provide minimal losses of minerals in terms of scooping.

When using transverse technologies, there are two stages of mining development:

1. formation of the initial capacity with the transportation of overburden on the external dumps;
2. mining of the main part of the pit field with the transportation of overburden on the internal dumps.

In case of deepening transverse and shuttle-layered mining systems, overburden rocks of the initial capacity are transported to the surface within the pit boundaries, forming temporary dumps.

During mining, the rocks of the initial capacity can be moved by dump trucks, belt conveyors, as well as by means of extraction equipment – draglines. Combined types of transport also can be used.

Subsequent stages of development provide for placement of rocks in the mined-out area, formed as the mining front of the quarry moves.

Mineral in all variants is transported from faces to the surface place of receiving.

Development of the rock mass of the main part of the quarry field at transverse technology is carried out by rope shovels (also by hydraulic shovels) with loading on dump trucks or conveyors and removal of rocks on internal dumps, and the mineral – on a warehouse.

In the shuttle-layered mining system, the rock is also worked out by draglines with laying it on a direct dumping scheme in the mined-out area.

Draglines can also be used to strip the lower benches in other variants of transverse technology.

In all cases, coal is provided by draglines to the transport benches for its subsequent transportation to the place of receiving.

Transport overburden is stored on the external or internal dumps by the same schemes as in the longitudinal mining system.

The questions of opening at transverse systems of development are solved separately for freight flows of initial capacity and for freight flows of the main part of the pit field [5].

Opening of working benches of the initial cut length of the capacity, formed by the longitudinal deepening technology, is carried out by external and internal trenches, the route of which has also longitudinal direction (Fig. 7a).

On Fig. 7: D_q – quarry depth, W_q – quarry width, L_{ic} – surface length of initial cut, L_{bic} – bottom length of initial cut, α_s – dip angle, γ_{nf} – angle of non-mining flank.

At formation of initial capacity by transverse deepening technology opening of working benches is carried out by the internal trenches passing on a working flank (end) of a site and having a transverse direction of a route (fig. 7b).

As the front of the work is moving, the internal trenches of the working end can be moved to the non-working flank and the route will have longitudinal direction.

Removing of internal trenches from the working benches to a non-working flank at the transverse technology of the initial capacity excavation is especially necessary when the parameters of the site does not allow to place the trench on the lower working benches.

Otherwise, the freight flows of the benches, the length of which is less than the length of the inclined trench, should be provided with excavators on the direct dumping scheme with the removing of rock and minerals to the overlying transport benches.

Selection of the scheme of opening the working benches of the initial capacity should take into account the second stage of mining operation, when the main part of the quarry field will be developed with the transverse movement of the front of the work and the placement of overburden in the mined-out area.

Conclusions

The main technological requirement for the development of horizontal deposits is the placement of all operational overburden in the mined-out space of the pit.

Only overburden construction volumes are located outside the pit. Therefore, there are two main stages of development of open-pit mining operations in horizontal deposits:

- mining and construction works and commissioning of the open pit;
- development of the open pit design capacity and its operation.

In the first stage, overburden and mineral freight flows are directed outside the open pit. Mining and construction works of this period are aimed at creating necessary reserves of mineral resources and capacity inside the open pit for operational overburden, as well as to ensure the freight flows of mineral resources and overburden (opening of winning benches) to the beginning of the open pit operation.

In the second stage, overburden freight flows are directed to the quarry's mined-out space, and mineral freight flows are directed to the surface.

Freight flows of overburden and mineral may be transport or transportless depending on the thickness of the overburden and mineral.

During the operation of the opencast mine that is developing the flat seam, part of the overburden over the workable seam is mined out according to the direct dumping (transportless) scheme with its placing in the mined-out space. The rest of the overburden is mined out according to the transport scheme and removed to external or internal dumps.

Supply of freight flows of overburden is carried out by mine workings, which are located on the working flank and at the non-working ends of the pit.

For development of designed production capacity of the open pit it is sufficient to develop works on the bench of transportless overburden and on the winning bench, opening of which is carried out by a system of inclined semi-trenches for dump trucks, passed on the seam bottom in the mined-out area.

Due to the fact that the development of the deposit is carried out by transport technology and the freight flows of overburden and mineral are directed outside the pit, the opening systems can be represented by inclined trenches and underground workings.

It is envisaged to locate internal trenches on the non-working flank of the open pit as the coal seam is being worked out on its fall.

There are two options of placement of opening internal workings:

- at dip angles 15-30° internal workings will be represented by semi-trenches and the non-working flank of the pit will not require additional trenching.
- at dip angles 31-45° internal workings are inclined trenches and require the additional removal of the non-working flank to accommodate the mine workings themselves, adjacent areas and transport berms.

Development of steep deposits is carried out using transport technology with the removal of overburden and minerals outside the open pit. Therefore opening systems can be represented by inclined trenches (external and internal); inclined and steep trenches; inclined trenches and underground workings.

Development of steep deposits is carried out both from the hanging and from the lying sides of coal seam. That is why the quarry has two working flanks until reaching the maximum development of mining works.

This problem determines the placement of internal opening workings on mining flanks in the form of sliding ramps or periodic trenches.

The considered schemes of open-pit opening at longitudinal system of development show that the most typical stages are the periods of construction completion, development of designed capacity and maximum development of quarries mining operations. Subsequent stages up to the end of development will mainly present various schemes for the established method of opening at the maximum development of mining operations of the open pit.

At the same time, each of the methods of opening on particular stage can have a significant number of possible schemes of freight flow development depending on the conditions of bedding, the adopted

technological scheme with the appropriate mining and transport equipment, the parameters of freight flow, meeting environmental requirements.

The considered methods and schemes of opening of working benches of an open pit at transverse mining systems show their direct connection with formation of freight flows of overburden and a mineral which, in turn, depend on a direction of development of mining works.

At the same time, these systems do not strictly depend on the development of mining operations on the conditions of bedding, so in the formation of freight flows solution of the opening is determined by stages of development of the pit field.

A wide variety of methods and schemes for opening the working benches of the open pit with longitudinal and transverse mining systems requires special technical and economic assessment of possible options for specific conditions of opencast mining operations in a particular period of operation of the open pit.

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