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THE MECHANISM AND CHARACTERISTICS OF GROUND MOVEMENT AND STRATA FAILURE CAUSED BY MINING

Summary. The problem of ground movement and strata failure is considered as an important topic. It is usually related not only to the mine safety and coal production, but also to the surface environment protection as well. Depending on strata lithology and balance states of coalface - wall rocks five different forms of strata failure and surface subsidence over an extracted seam have been distinguished in the paper. These are as follows: "three zones" failure (caving zone, fractured zone and bending zone), arched caving and bending with a continuous ground movement, and massive caving or sinkhole failure accompanied by sudden subsidence of the ground. Main features of every strata failure and ground movement type are given and field examples from Chinese collieries are presented.

1. THE MECHANISM OF GROUND MOVEMENT AND STRATA FAILURE

As far as we know that after extensive mining activity, ground movement as well as strata failure from initiation, development and eventual completion, mainly depend on strata lithology, combination of rock layers and balance between coalface and wall rocks. It has been indicated that balance states of coalface and wall rocks might be classified as follows:

- The structure of cantilever beam or discontinuing beam - waste rock support. The roof in longwall coalface or main roof outside coalface is regarded as a beam with its one end on pillars, and the other end on the waste rock of goaf.
- The structure of natural arch or block arch - without any support. Natural arch or block arch is formed when roof collapses in goaf. But there is always a gap between waste rock and arched roof, so that waste rock does not give any support to the overlying strata.
- The structure of plate - without support or without pillar supp rt. During the process of caving, roof remains intact and bridging ver goaf without any support.

- The structure of plate and arch combination - without support or with pillar support. When the process of caving ends, the immediate roof forms a natural arch or a discontinuing arch while the main roof keeps intact and bridging.

Under the extensive mining activity, forms of ground movement and strata failure above goaf vary with balance states of coalface - wall rocks, which are shown as follows:

strata lithology	balance states of coalface-wall rocks	forms of strata failure	forms of surface subsidence
collapsible overburden	cantilever beam or discontinuing beam - waste rock support	"three zones"	continous deformation
strong rock layers above extracted seam	natural arch or block arch-without support	arched caving	continous deformation
massive strong rocks	plate-with or without support	bending	continous deformation
massive strong rocks	plate (arch) - without support or with unstable support	massive caving	sudden subsidence
weak overburden or soil		sinkhole	sudden subsidence

2. THE CHARACTERISTICS OF GROUND MOVEMENT AND STRATA FAILURE

Different types of ground movement and strata failure possess different characteristics as shown in following:

2.1. As longwall goaf area becomes larger, mining effect transfers from seam horizon to the earth's surface, provided that overburdon is collapsible (rock sample compressive strength: 100-800 kg/cm^2). As a result three zones are formed, namely: caving zone, fractured zone and bending zone. Sudden subsidence occurs when fractured zone reaches surface.

While one seam is extracted, caving height can be described as:

$$h_c = \frac{m - w}{k - 1}$$

where

M - mining height,

W - immediate roof convergence before caving,
K - dilatation constant of caving rocks.

While thick seams are under slicing mining, caving height can be described as:

$$h_c = \frac{m}{an + b}$$

where

n - numbers of sliced seams,
a,b - constants of strata lithology.

Fractured zone height can be shown as:

$$h_f = \frac{m}{an + d}$$

where

c,d - constants of strata lithology.

Surface subsidence may be formulated as:

$$W_{in} = W_{max}\left\{1 - \frac{1}{2}\, e^{-\beta\pi(\frac{1}{2} - \frac{x}{L})} \cos\left[\beta\pi(\frac{x}{L} - \frac{1}{2})\right]\right\}$$

$$W_{out} = \frac{1}{2}\, W_{max} e^{-\beta\pi(\frac{x}{L} - \frac{1}{2})} \cos\left[\beta\pi(\frac{x}{L} - \frac{1}{2})\right]$$

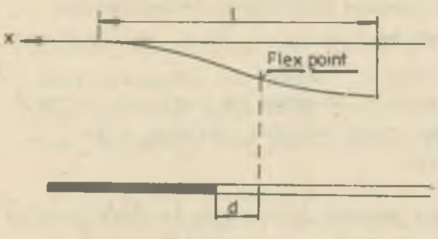

Fig. 1. The deviation of flex point

where

W_{in} - deflection within flex point of moving trough,

W_{out} - deflection outside flex point of moving trough,

W_{max} - maximum deflection of moving trough,

L - half length of moving trough,

β - constant of strata lithology ($1 \leq B \leq 2$; B increases with rock strength),

d - deviation of flex point (figure 1).

"Three zones" strata failures are most commonly seen while the bedded mineral is under extraction, and obvious laws can be derived from observations in site. The characteristics of strata failure are:

- The maximum height of caving zone and fractured zone increases with mining heights in the relation of fractional function.
- The extent and forms of caving zone and fractured zone might be illustrated by figure 2.

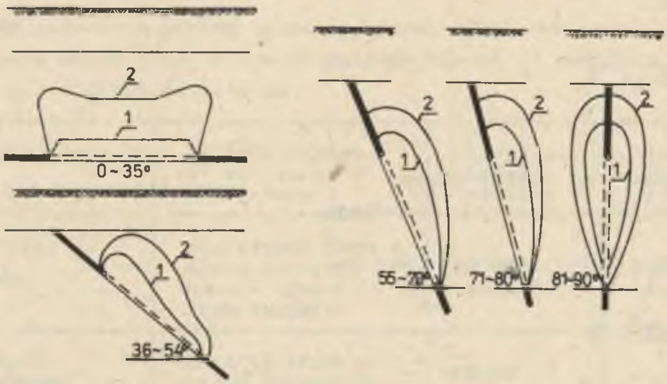

Fig. 2. Distribution of caving zone and fractured zone
1 - Caving zone, 2 - fractured zone

- Generally speaking, strata within fractured zone moves intactly.
- Surface fissures usually occur towards the verge of moving trough, while the fissures extend only a few meters in alluvial strata.
- When overlying strata consists of weak, plastic rocks, there generally has no access for water to penetrate into caving zone or fractured zone through surface fissures.

The characteristics of surface movement are:

- The size of the subsidence trough is larger than that of extracted area. Outside flex point of the trough is extension zone, while inside it is compression zone.
- The surface subsidence and deformation are related to various factors such as mining height, mining methods, roof control, mining size, mining depth and strata lithology, etc.

2.2. Where one or several strong rock layers (rock sample compressive strenght: > 800 kg/cm^2) appear over extracted seam, arched caving zone will be probably right under that or those layers, resulting in a minimum settlement on the surface (figure 3).

Caving height can be described as:

$$h_c = \frac{m}{k - 1}$$

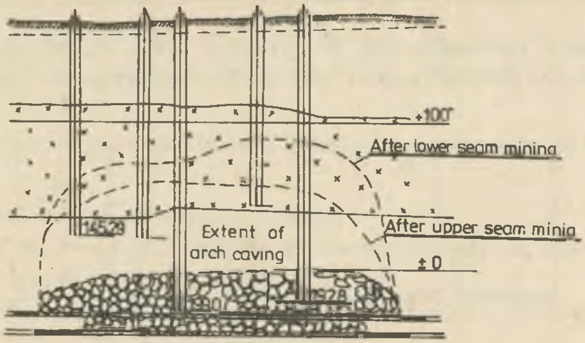

Fig. 3. Arch caving

Subsidence of strong rock layers is formulated as follows:

$$W = \frac{2\varrho g L^2}{E\pi^3}\left[(1+\mu) + \frac{2\,\mathrm{sh}\,\frac{\pi h}{L}}{\mathrm{sh}\,\frac{\pi h}{L} - \frac{\pi h}{L}}\right]\left(1 + \cos\frac{\pi x}{L}\right)$$

where

ϱg - rock average density,
E - rock Young's modulus,
μ - rock Poisson constant,
h - thickness of strong rock layers,
L - half length of strong rock layers, within the extent of strata movement.

The characteristics of strata failure of arched caving are:

- Strata failure is restricted in the vicinity of extracted seams.
- Caving height increases towards the center of the goaf.
- Caving occur sometimes suddenly, at times intermittently, depending on the lithology and combination structure of the strata.

2.3. If the massive strong rocks are lying above the extracted area with pillar support, strata collapse might be avoided as long as the ratio of the area of pillars to that of panel is greater than 30-35%, and strong rock layers are in a position to bridge thus giving rise to a maximum surface deflection only about 5-15% of the extracted height. Such method as underground strip mining used in China is one of the effective ways to reduce surface subsidence.

2.4. If most parts of overburden are strong rocks, sudden collapse is likely to happen when mining depth is rather small (e.g. 100-150 m), and pillar sizer occupy less than 30-35% of whole extracted area. As a result, strong rock layers are incapable of bridging, that might lead to an unexpected extensive strata failure and surface subsidence (fig. 4).

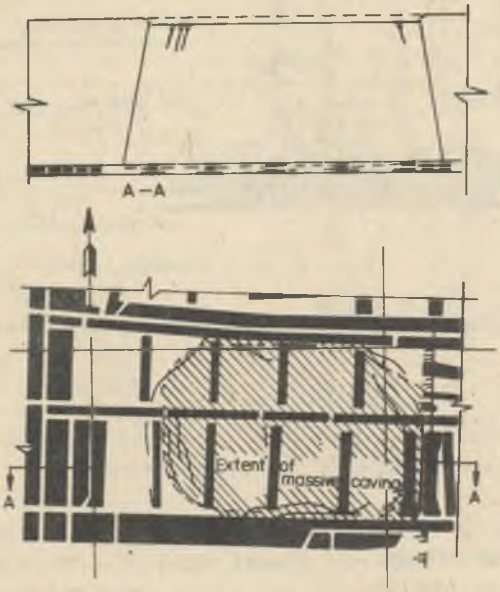

Fig. 4. Massive caving

In Datong Coal Mine Region of China, very strong conglomerates and sandstones dominate overlying strata (rock sample compressive strength: 800-2000 kg/cm^2). Sudden strata and surface cavings frequently occurred when extracted areas extended to thousands of square meters.

The characteristics of massive caving are:

- Extensive caving occurs suddenly. According to the experiences in Datong coal mines, the average caving areas range from 20000-40000 m^2.
- Caving occurs when mining depth is small (usually less than 100 m, with the exceptions of 100-300 m occasionally).
- The outline of caving strata is drawn in figure 4 (caving angle: 65-85°)
- The shapes of caving are usually circles or ovals which develop along the boundary of panel. Caving depthes on the surface are ranging from 0.5 to 4 m.
- To the extent of mining area, large cracks appear on the surface after caving. The maximum widths of the cracks are 0.1-0.5 m; and their depths are unmeasurable.
- Massive caving often leads to tragic damages to the coalface as well as the surface.

- There is usually an omen of caving before its happenning, such as coal pillar yielding, wooden support cracking, and coalface convergencing, etc.

The characteristies of surface subsidence caused by massive caving are:

- Surface deflection is usually small.
- The extent of surface fissures is restricted within the flex point of moving trough above extracted area.
- The part of moving trough outside the flex point is likely to heave slightly.
- Sudden surface subsidence occurs long after the extensive mining area was extracted.

2.5. Sinkholes might arise where very weak rocks dominate overlying strata, or mining depth is small, or mining activity is close to alluvium (figure 5).

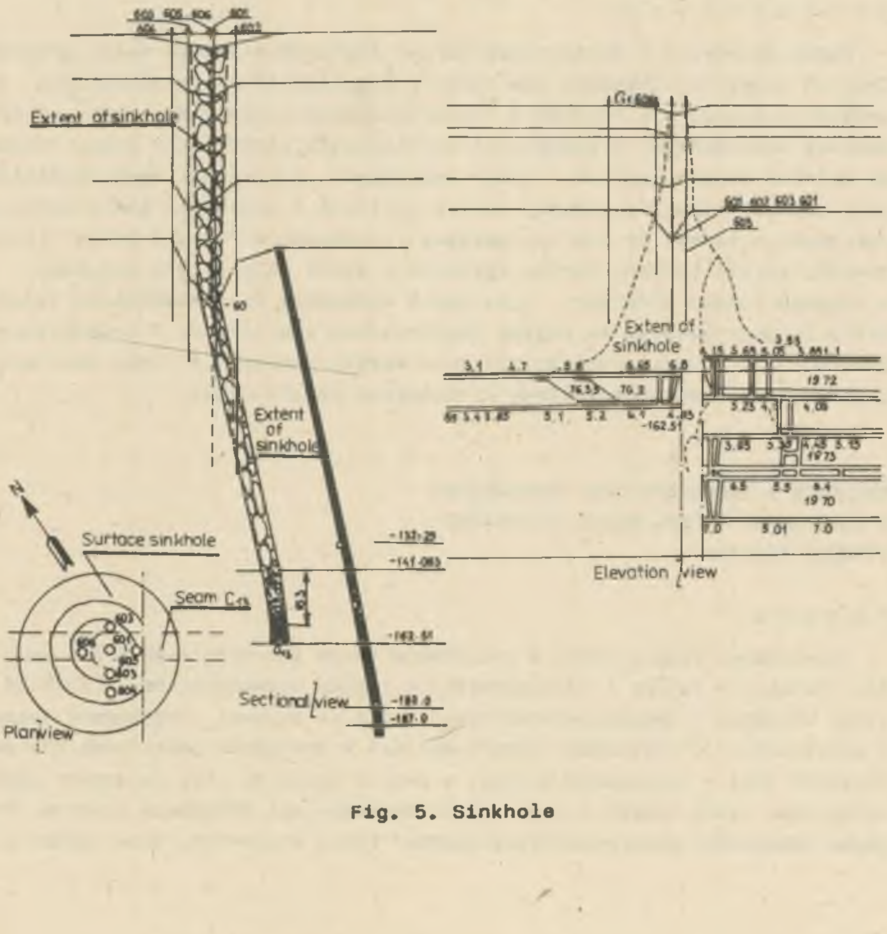

Fig. 5. Sinkhole

The conditions under which sinkholes might be induced are:

- Greater seam angle, strong rock strength of coal measures and weak coal strength.
- Caving coal and rocks in goaf being unable to accumulated on the spot.
- Abundant water supply in the overburden of extracted area.
- Mining under steep seams sinkholes may occur repeatly at the same place.

Recenzent: Prof. dr hab. inż. Mirosław Chudek

Wpłynęło do Redakcji w grudniu 1985 r.

MECHANIZM I CHARAKTERYSTYKA PRZEMIESZCZEŃ GÓROTWORU ORAZ ZNISZCZENIE WARSTW SKALNYCH WYWOŁANE ROBOTAMI GÓRNICZYMI

S t r e s z c z e n i e

Ruchy górotworu i zniszczenie warstw skalnych stanowią ważny problem. Jest on zazwyczaj związany nie tylko z bezpieczeństwem w górnictwie i produkcją węgla, ale również z zabezpieczeniem powierzchni terenu i środowiska naturalnego. W zależności od litologii górotworu i stanu równowagi układu: ściana węglowa - skały otaczające, w artykule wyszczególniono pięć różnych form zniszczenia warstw skalnych i osiadania powierzchni nad wybranym pokładem. Są one następujące: zniszczenie "trzystrefowe" (strefa zawału, strefa spękań, strefa zginania), zawał sklepiony i zginanie z ciągłym ruchem górotworu oraz zawał całkowity lub zniszczenie zapadliskowe z towarzyszącym mu nagłym zapadnięciem się terenu. Przedstawiono główne cechy każdego typu zniszczenia warstw skalnych i ruchu górotworu, i podano odpowiednie przykłady z chińskich kopalń węgla.

МЕХАНИЗМ И ХАРАКТЕРИСТИКА ПЕРЕМЕЩЕНИИ И РАЗРУШЕНИЙ ГОРНЫХ ПОРОД, ВЫЗВАННЫЕ ГОРНЫМИ РОБОТАМИ

Р е з ю м е

Перемещения горных пород и разрушение слоёв является важной проблемой. Это связано не только с безопасностью в горной промышленности и добычей угля, ио также с предохранением поверхности и охраной окружающей среды. В зависимости от литологии горного массива и состояния равновесия системы: угольная лава - окружающие породы, в работе выделены пять различных форм разрушения слоёв породы и оседания поверхности над выбранным пластом. Эти формы следующие: разрушение"трёхзоновое" (зона обрушения, зона трещин и

зона сгибания) , обрушение сводчатое и сгибание при непрерывном перемещении горных пород, а также полное обрушение или разрушение сопровождающееся неожиданным провалом поверхности. Представлены главные отличительные черты каждого из типов разрушений слоёв пород и передвижений горного массива, а также представлены соответствующие примеры из практики китайских угольных шахт.