

# Outbursts in China

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- 1 Introduction
- 2 General understanding of OB
- 3 OB cases
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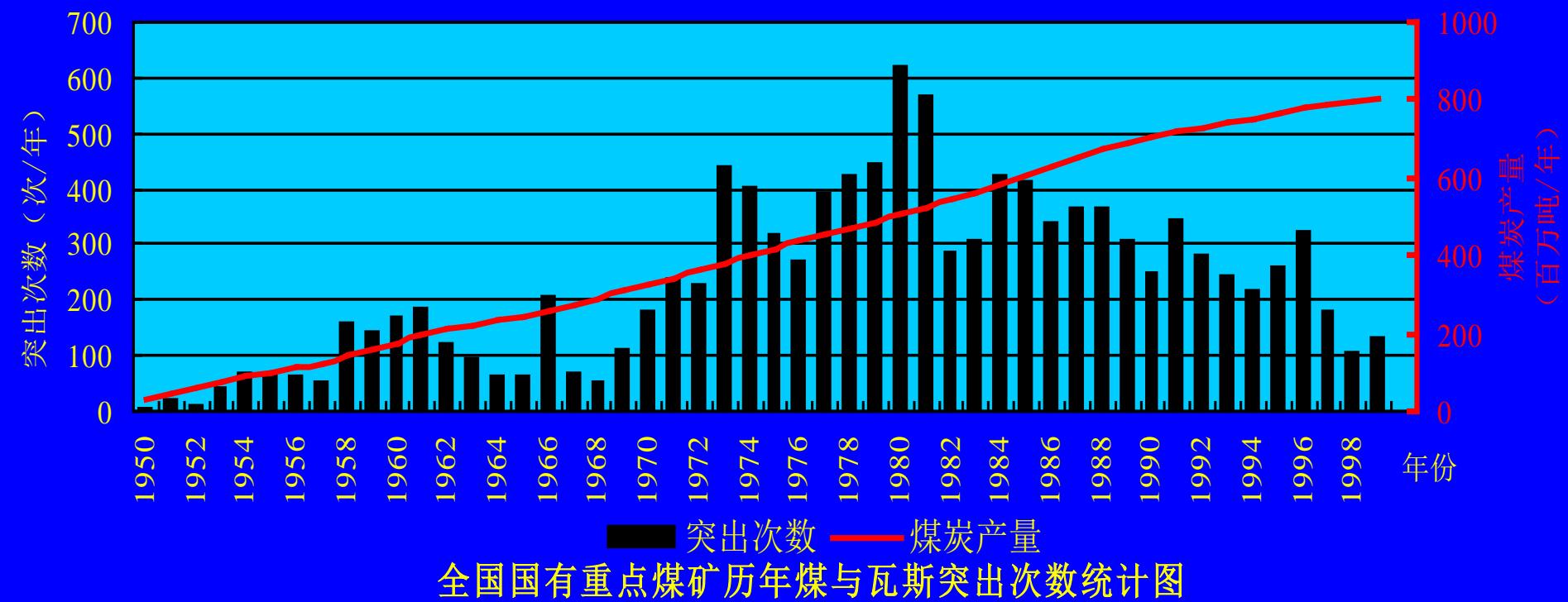


# 1 INTRODUCTION

- OB occurrence is very serious in China
- 1950.5.2, first recorded in China
- In 1975.8.8, the largest OB in China: 12780t of coal、 $1.4 \text{ M m}^3$  of  $\text{CH}_4$
- Marjory OB:  $\text{CH}_4$  & Coal
- Minority OB:  $\text{CO}_2$  & Rock, 1050t of rock,  
 $240,000 \text{ m}^3 \text{ CO}_2$

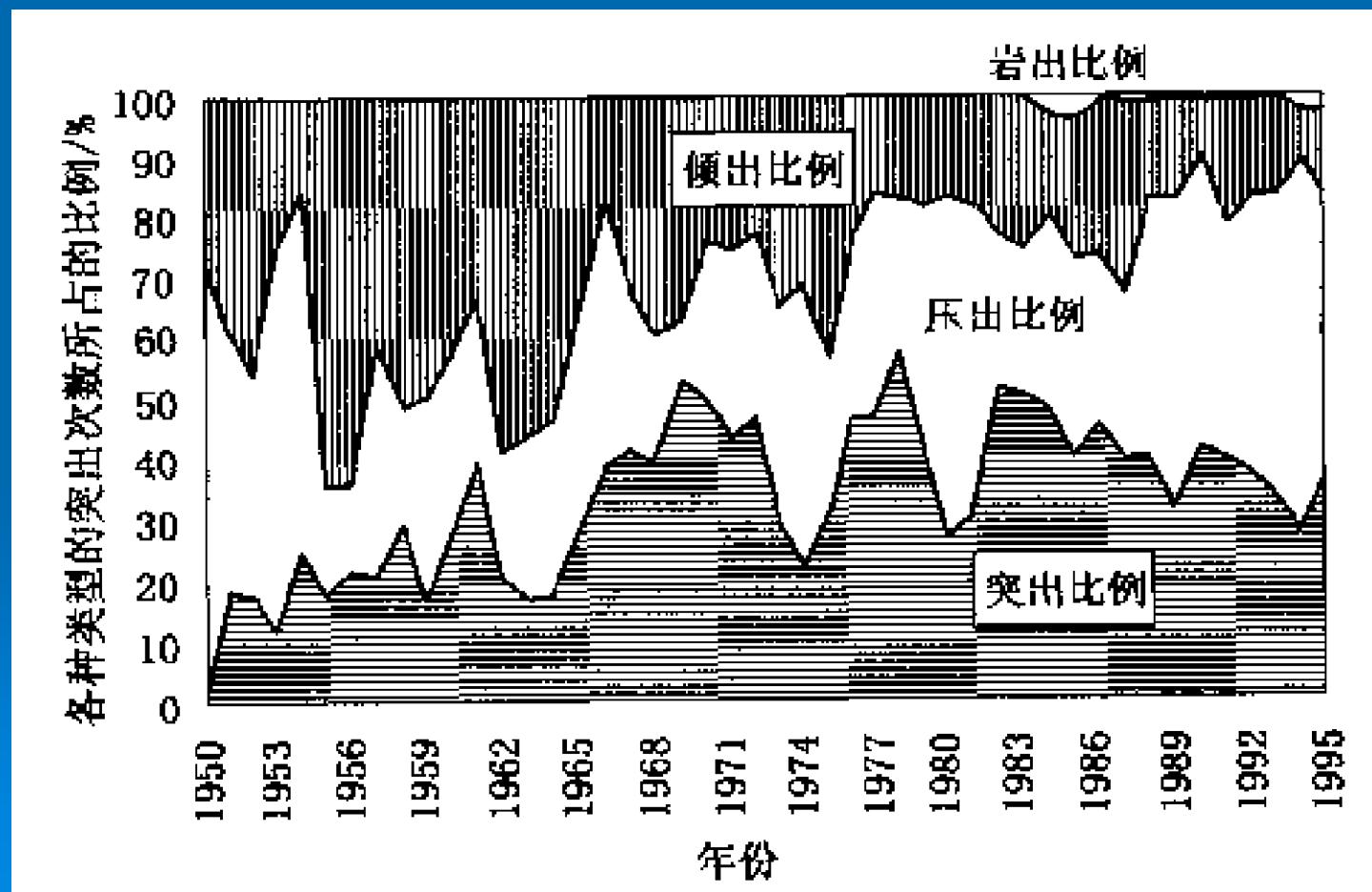
# 1 INTRODUCTION

Number of OB occurrence in state-owned coal mines  
in China from 1950 to 2000



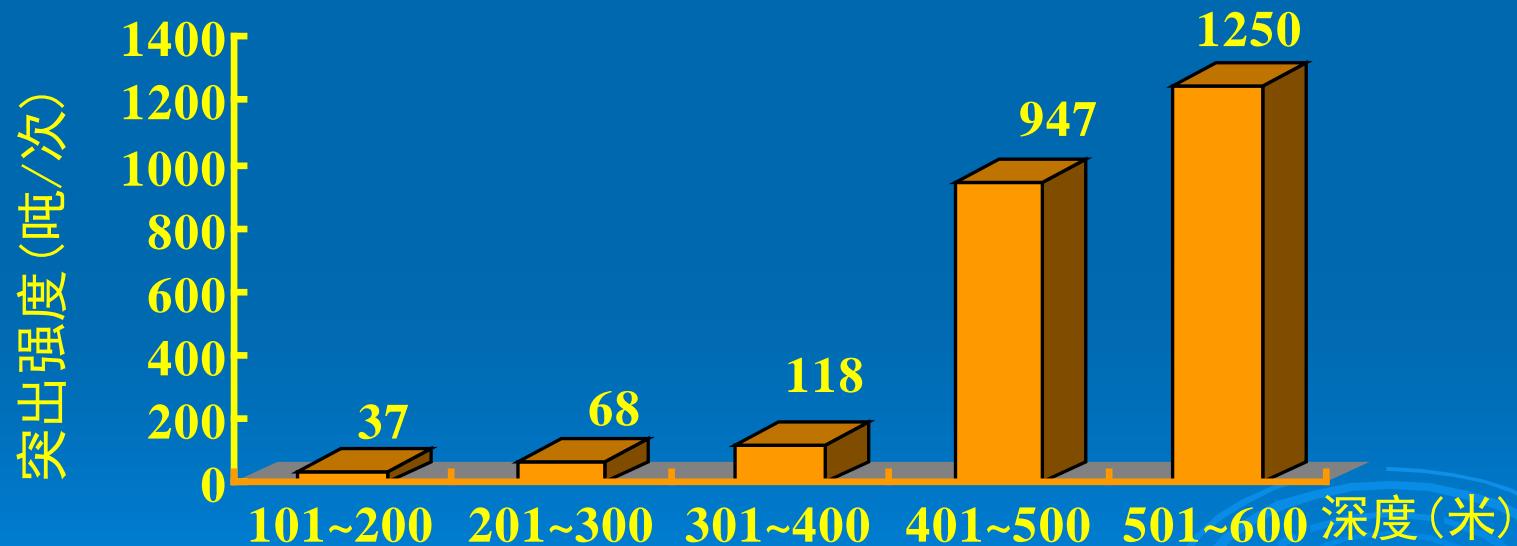
# 1 INTRODUCTION

Categories of OB occurrence: coal & gas bursting, coal bursting due to stress and gravity, rock bursting



## 1 OB VS Mining Depth

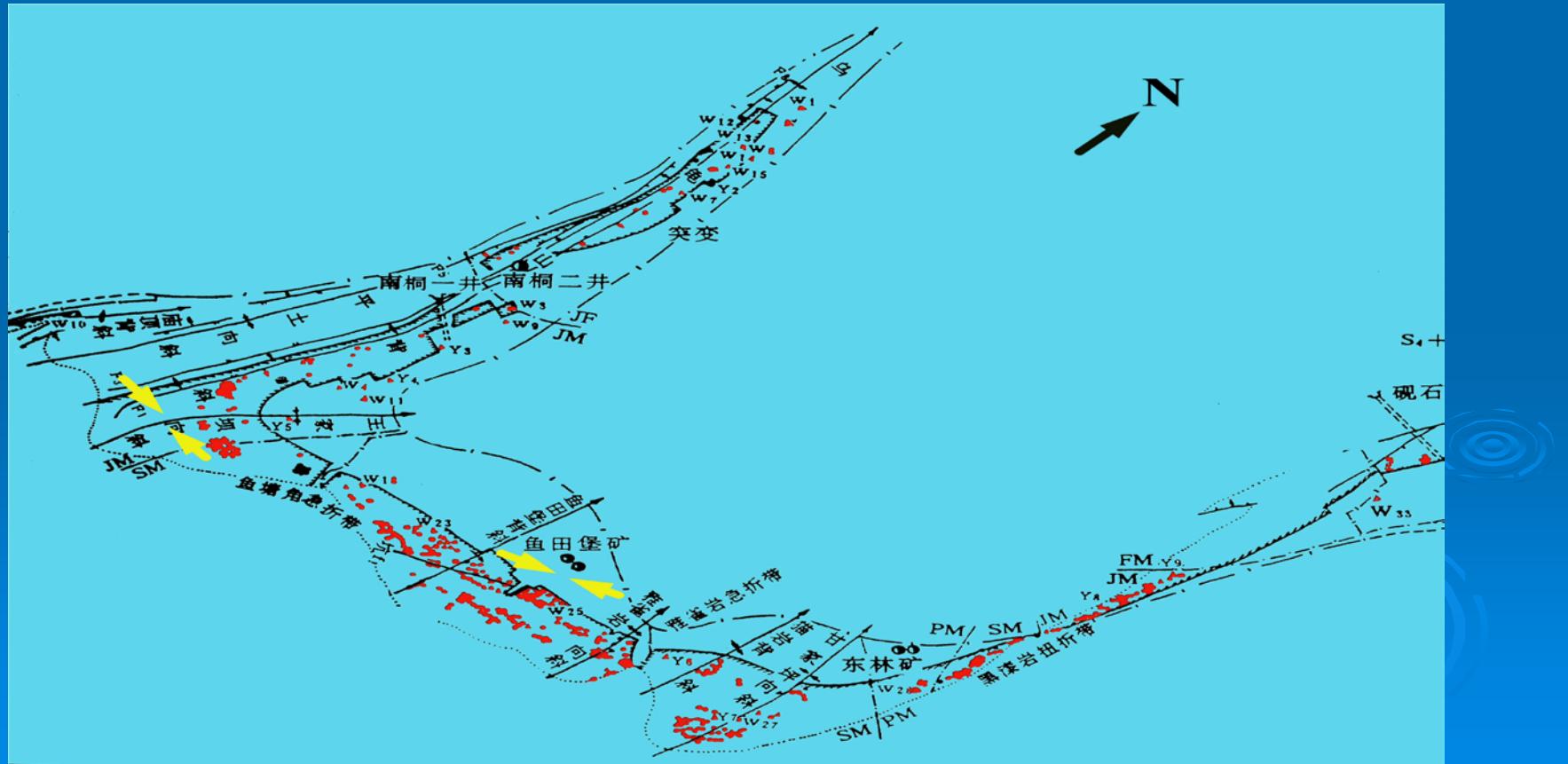
The depth occurred OB in China is from 50 to 600 m, different in various areas.



重庆地区突出强度与深度的关系

# CUMT 2 GENERAL UNDERSTANDING OF OB

2 OB is associated with geological structures (faults, folds, volcanic rock intrusion and variation of coal seams such as thickness, dip and orientation) and structural stress



3 In the zone of overlapping stress due to face and roadway extraction, OB risk is higher.

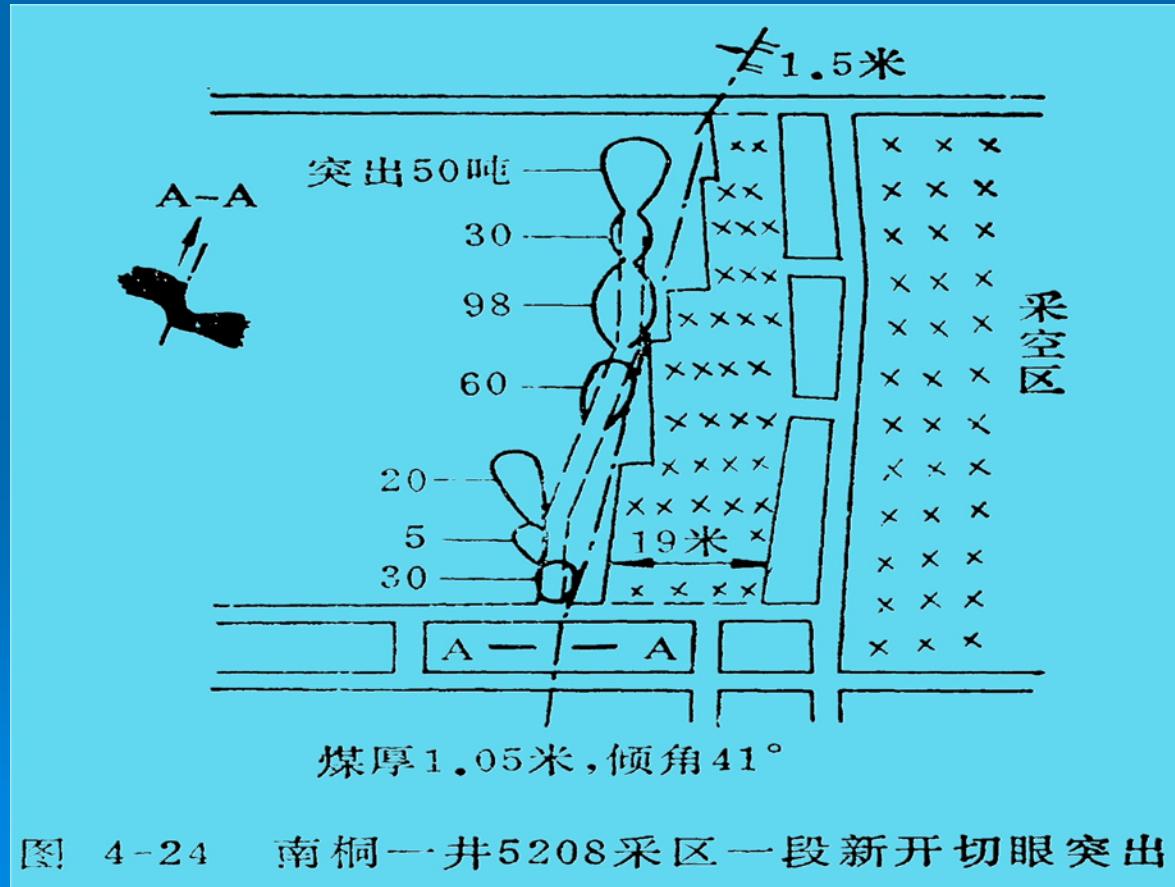
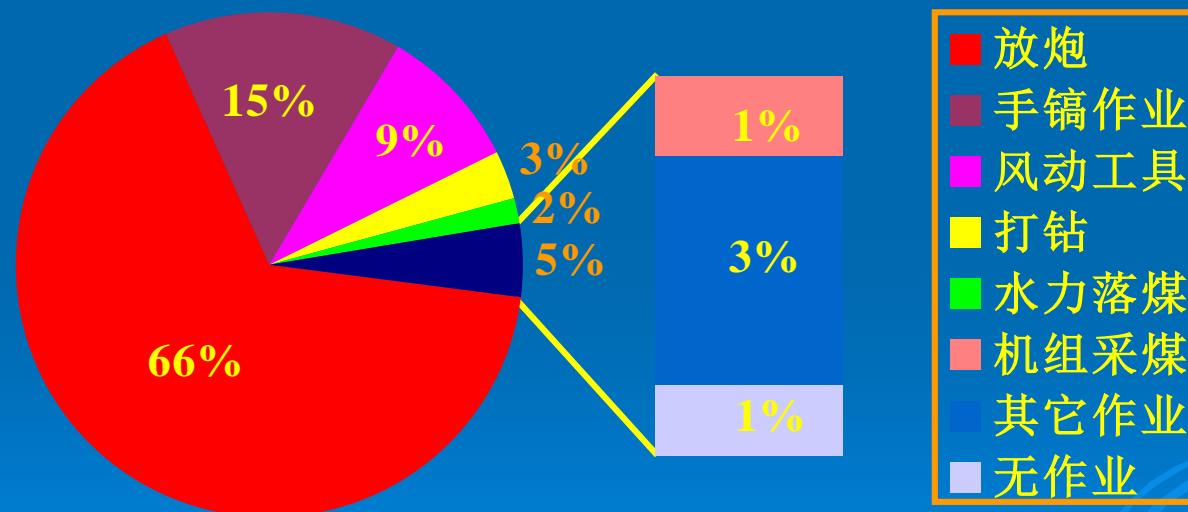


图 4-24 南桐一井5208采区一段新开切眼突出

4 The higher gas pressure, the higher OB risk.

5 OB vs mining methods, shotfiring is the most risky.



采掘作业与突出的统计关系（样本数：6427）

## 6 Precursors of OB occurrence

- **Audio- and non audio- precursors prior to OB occurrence**
- **Audio precursors include cracking, thundering etc**
- **Non audio- precursors include weighing of supports, rib and face cracking and falling, borehole heavily deforming, gas emission variation, irregular beddings, bursting while drilling, coal softening, coal dust increasing, etc.**

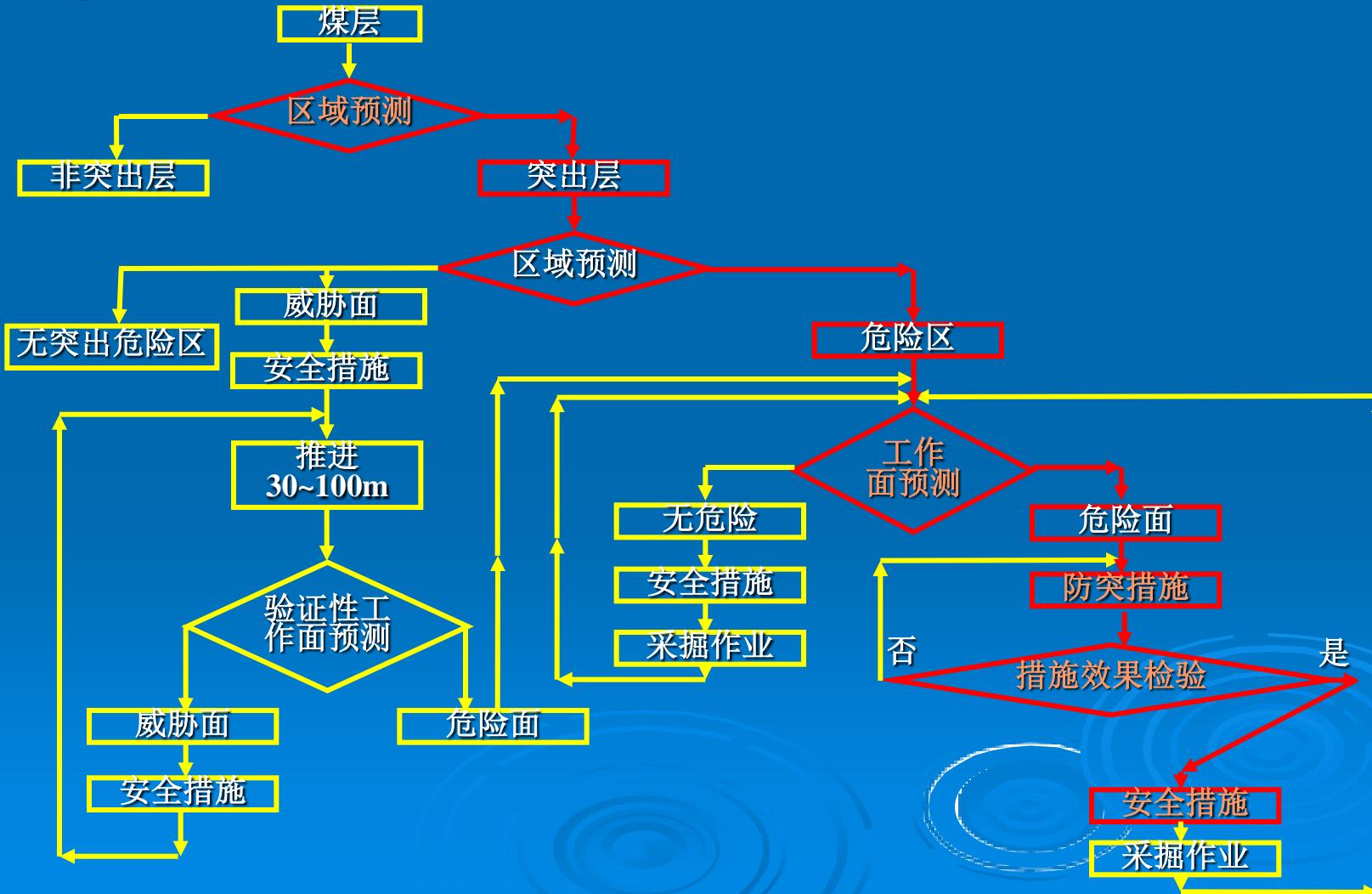


## 3 OB CASE

Oct. 20, 2004, an OB and resultant gas explosion in Daping Mine in Zhengzhou.

# 4 OB PREDICTION AND CONTROL (GUIDELINE)

## 1 Implementation Procedures





# 4 OB PREDICTION AND CONTROL (GUIDELINE)

## 2 Regional OB Prediction

### Single Index

Index	Coal damage classifications	Initial desorption rate of coal (mmHg)	Coal strength coefficient $f$	Seam gas pressure (MPa)
Threshold	III, IV, V	$\geq 10$	$\leq 0.5$	$> 0.74$

### Composite Index

$$D = \left( \frac{0.0075H}{f} - 3 \right) (p - 0.74)$$

$$K = \Delta P / f$$

$D$	$K$	
	Anthracite	Other coals
$\geq 0.25$	$\geq 20$	$\geq 15$



# 4 OB PREDICTION AND CONTROL (GUIDELINE)

## 3 Coal face OB Prediction

**Cross measure roadway - coal/rock face**

- Composite Index;
- Coal Cuttings Desorption Index ( $\Delta h_2$ ,  $K_1$ )

Threshold Values	
$\Delta h_2$ (Pa)	$K_1$ (mL/g.min <sup>1/2</sup> )
Dry coal: 200	0.5
Wet coal: 160	0.4



# 4 OB PREDICTION AND CONTROL (GUIDELINE)

## 3 Coal face OB Prediction

### Inseam roadways - coal face

a) Initial gas flow rate from borehole ( $q$ ):

Threshold value ( $q_m$ )				
Coal volatility $V_{daf}$ (%)	5~15	15~20	20~30	>30
$q_m$ (L/min)	5.0	4.5	4.0	4.5

b)  $R$  Index ( $R_m=6$ )

$$R = (S_{\max} - 1.8)(q_{\max} - 4)$$

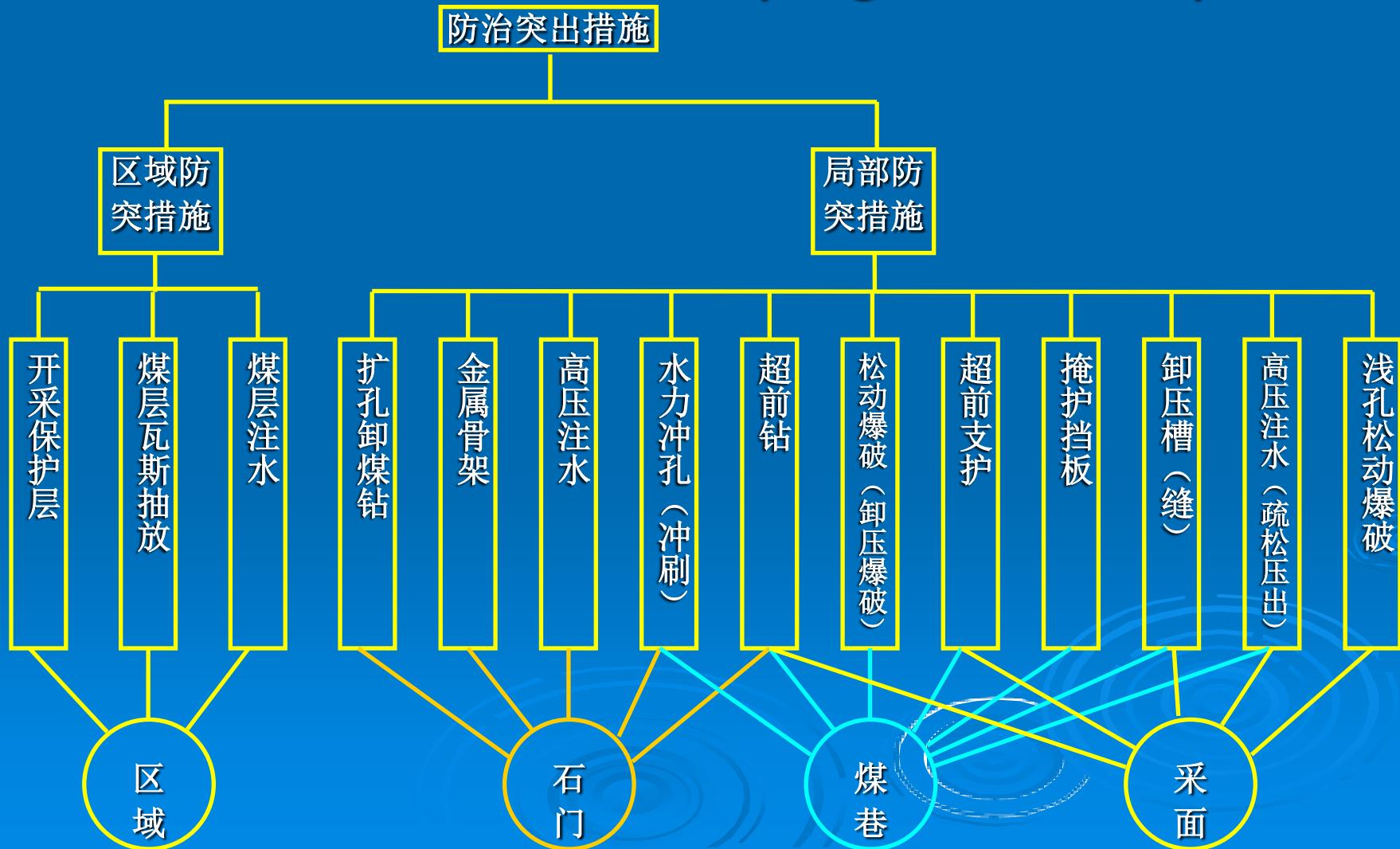
c) Coal cutting index

Threshold value of coal cutting index			
$\Delta h_2$ (Pa)	$S_{\max}$ kg/m	$L/m$	$K_1$ (mL/g.min <sup>1/2</sup> )
200	6	5.4	0.5



# 4 OB PREDICTION AND CONTROL (GUIDELINE)

## 4 OB Prevention Measures (Regional/Local)





# 4 OB PREDICTION AND CONTROL (GUIDELINE)

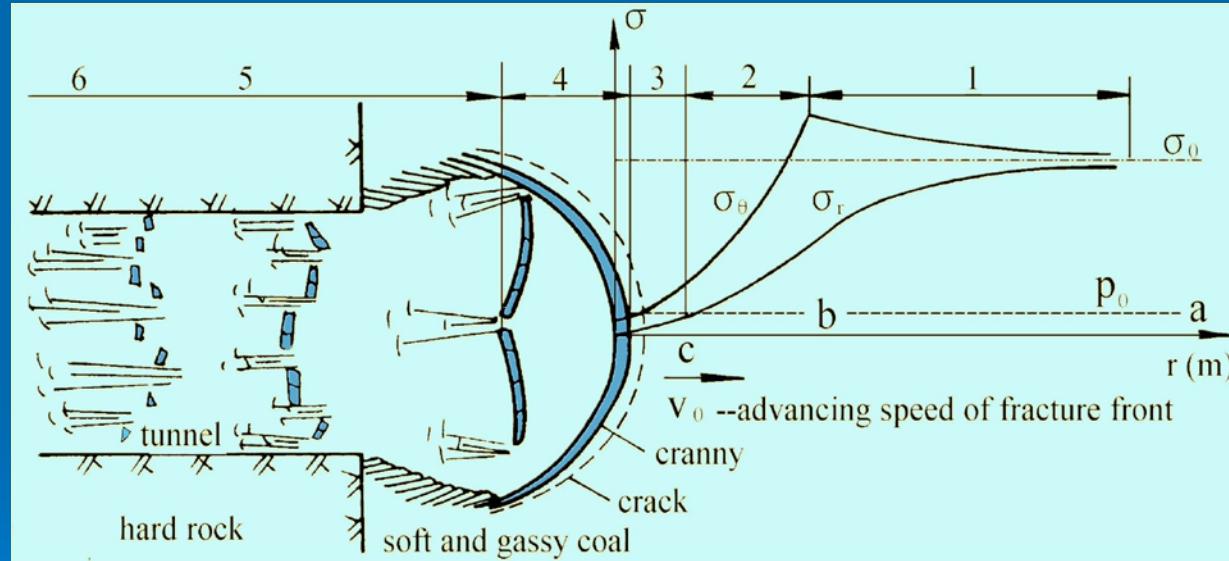
## 5 Safety Protection Measures

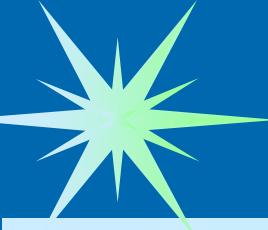
- Shake Shotfiring
- Remote Shotfiring
- Underground Refuge
- Self Rescue System of Compressed Air
- Isolated Aerophore

# 5 RESEARCH STATUS

## 1 Spherical disk failure theory of OB

煤与瓦斯突出的球壳失稳理论



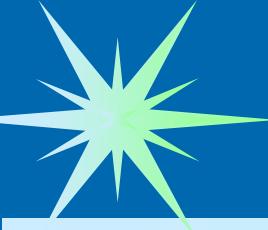


# THEORY OF OB OCCURENCE SPHERICAL DISK FAILURE

## Mechanics conditions of OB occurrence

(1) Ground stress generates shear failure of coal, then form cracks in coal

$$\sigma_{\theta} \geq \frac{1 + \sin \varphi}{1 - \sin \varphi} \sigma_r + \frac{2K \cos \varphi}{1 - \sin \varphi}$$



# THEORY OF OB OCCURENCE SPHERICAL DISK FAILURE

## Mechanics conditions of OB occurrence

**(2) Cracks expand under gas pressure, then form spherical disk**

$$P_{if} - P_2 \geq M_1 \frac{K_{1c} \sqrt{\pi}}{2\eta \sqrt{a}}$$



# THEORY OF OB OCCURENCE SPHERICAL DISK FAILURE

## Mechanics conditions of OB occurrence

**(3) Spherical disk fails and thrown out under gas pressure**

$$P_{im} - P_2 \geq [1 - 0.00875(\phi_1 - 20^\circ)](1 - 0.000175 \frac{R_i}{t_i})(0.3E \frac{t_i^2}{R_i^2})$$

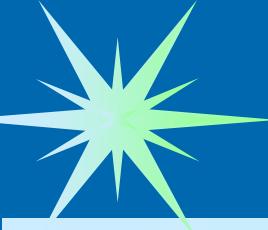


# THEORY OF OB OCCURENCE SPHERICAL DISK FAILURE

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## Energy Dissipation in OB initiation

**According to the spherical disk failure theory, the key for OB to occur is the gas initial expansion energy.**

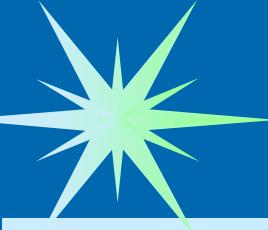


# THEORY OF OB OCCURENCE SPHERICAL DISK FAILURE

## Gas initial expansion energy

Measuring Apparatus



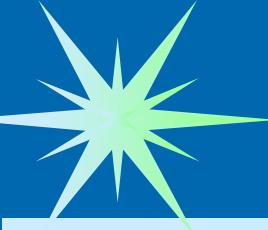


# THEORY OF OB OCCURENCE SPHERICAL DISK FAILURE

**Test validation of spherical disk failure theory**

**OB in the  
test**

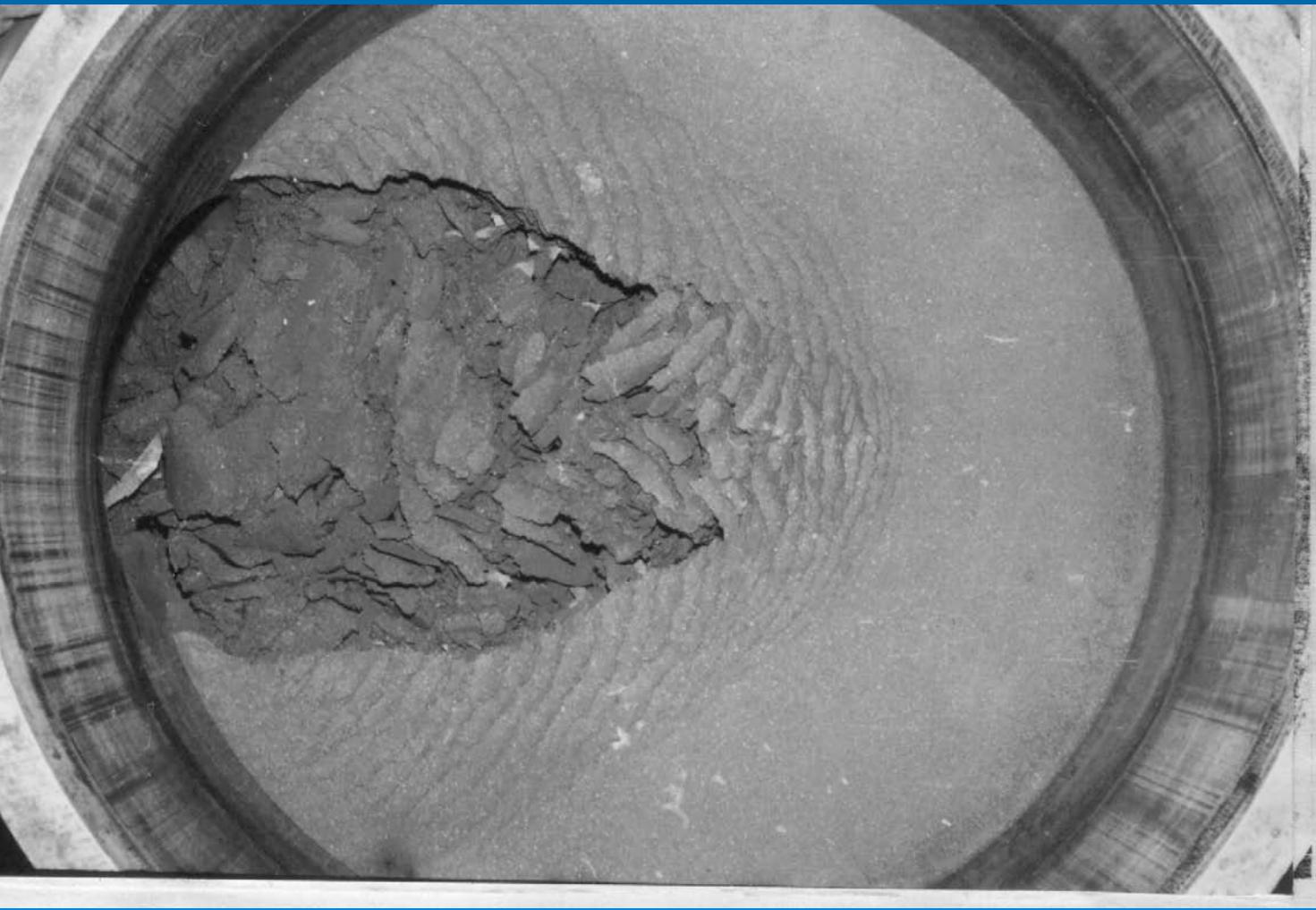


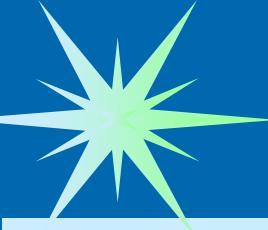


# THEORY OF OB OCCURENCE SPHERICAL DISK FAILURE

**Test validation of spherical disk failure theory (1)**

**Spherical  
disks**

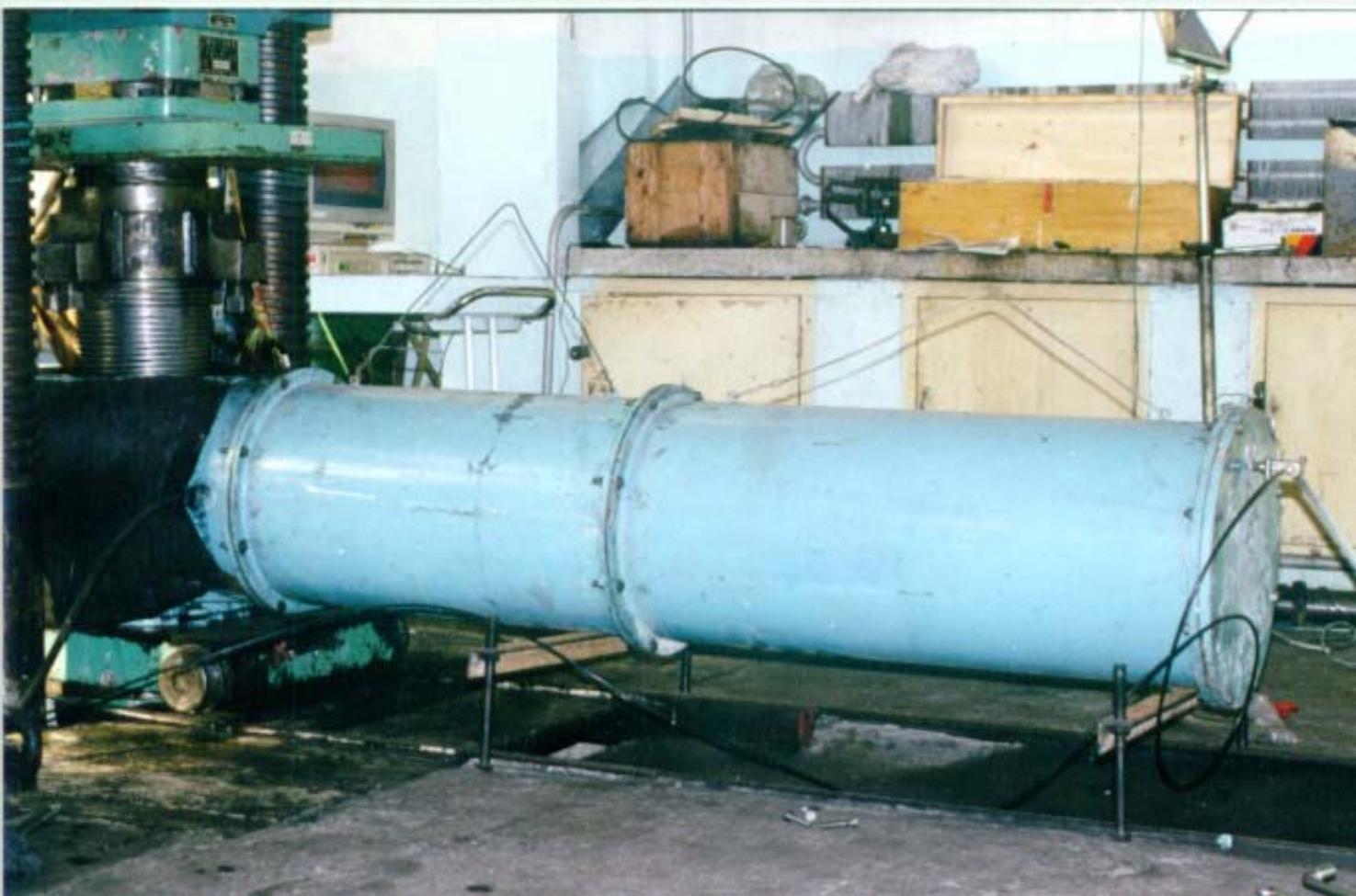


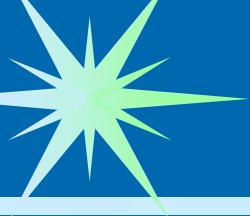


# THEORY OF OB OCCURENCE SPHERICAL DISK FAILURE

## Test validation of spherical disk failure theory (2)

Through increasing the air pressure in the model tunnel to prevent spherical disk from failure, OB can't occur.

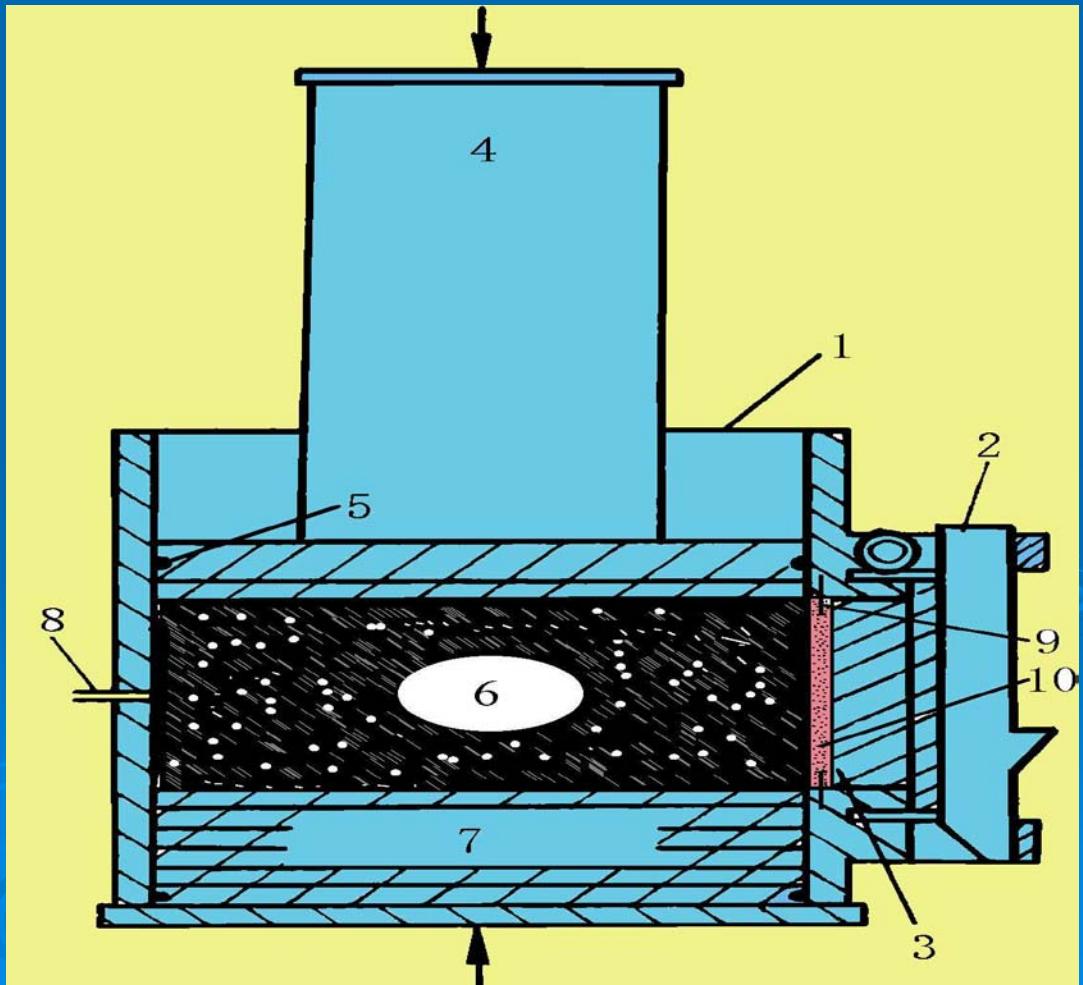




# THEORY OF OB OCCURENCE SPHERICAL DISK FAILURE

Test validation of spherical disk failure theory (3)

Delayed- OB

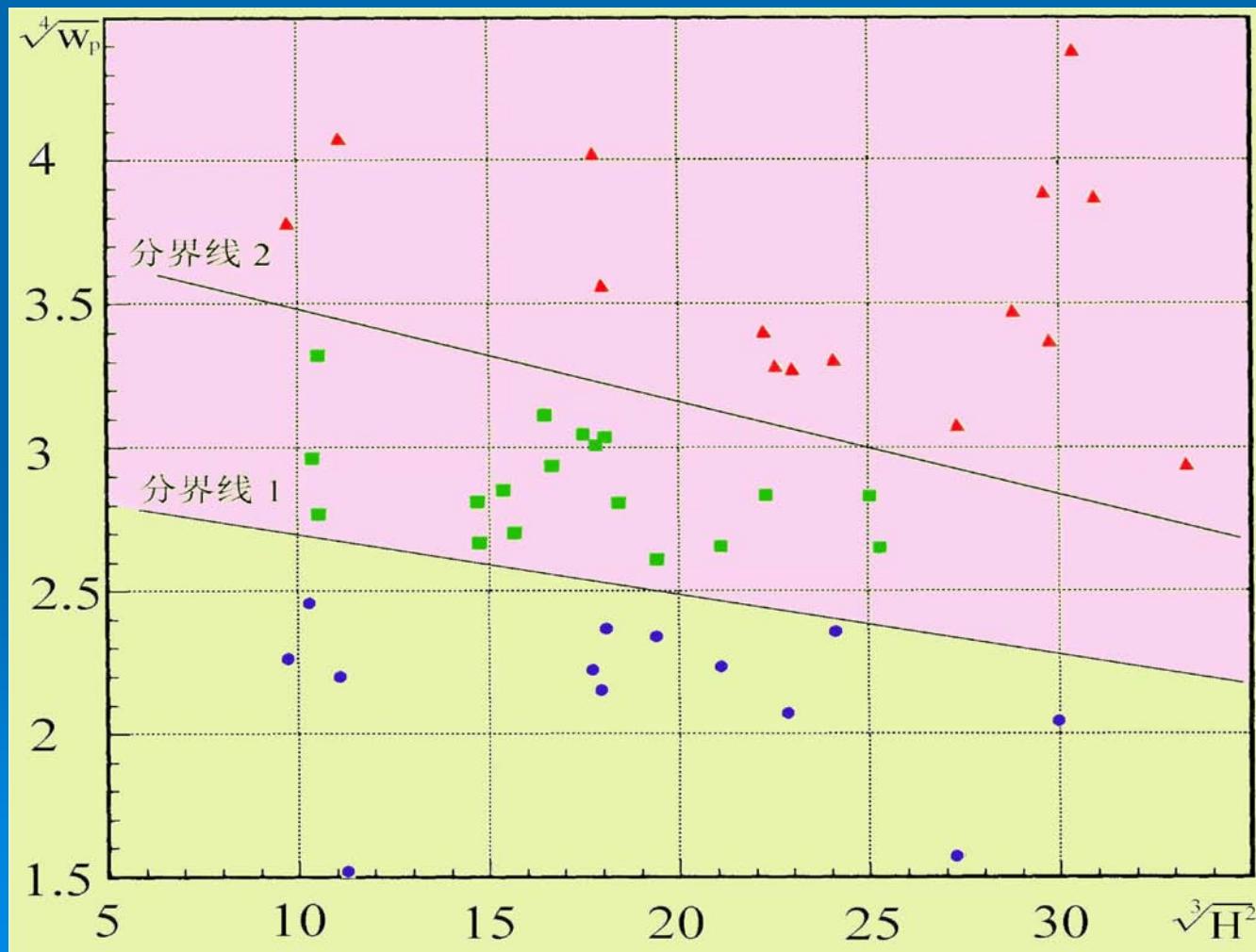


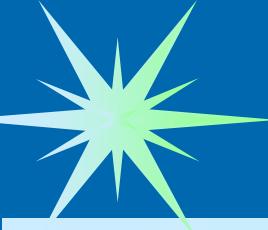


# THEORY OF OB OCCURENCE SPHERICAL DISK FAILURE

## Test validation of spherical disk failure theory (4)

The test results (OB or Non- OB) can be classified by the parameters of gas initial expansion energy and thickness of soft coal





# THEORY OF OB OCCURENCE SPHERICAL DISK FAILURE

## Test validation of spherical disk failure theory (5)

The variation in coal temprature in OB initiation is measured, the increase of temprature near cracks is 50 centigrade degree.

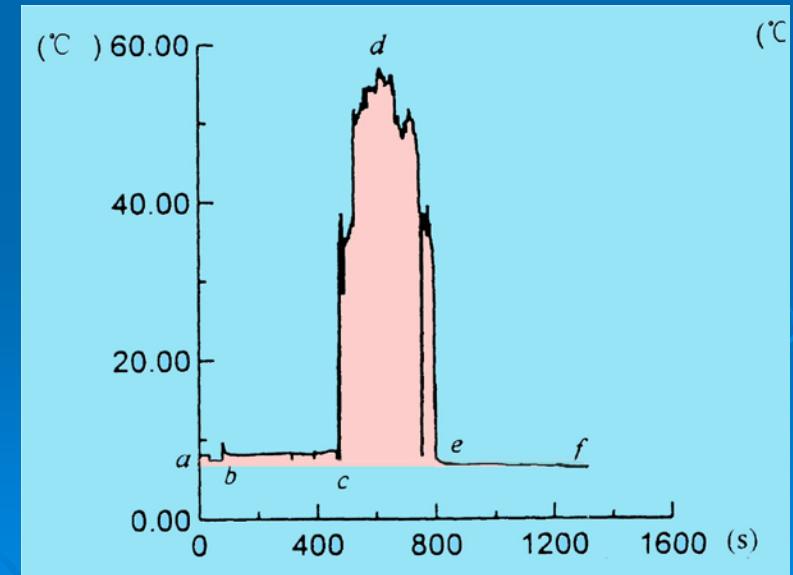
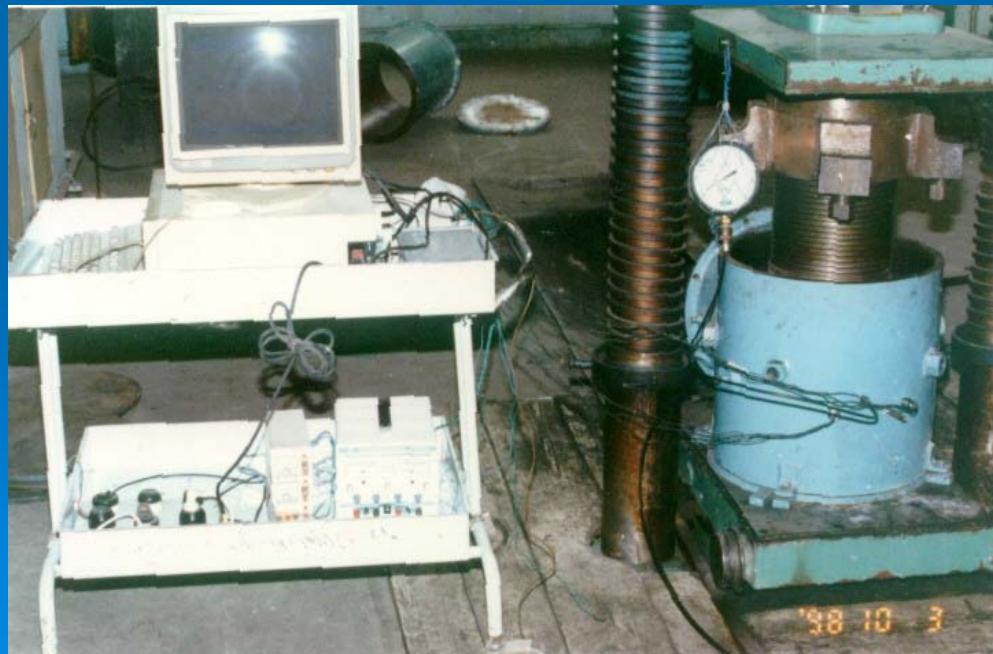


图 4.5-1 1号传感器温度变化曲线



## 5 RESEARCH STATUS

### 2 Regional OB Prediction method

**Minimum gas pressure of OB occurrence**

- statistically

$$p_{\min} = 5(0.1 + 0.017v^r f) \text{ MPa}$$

→ OB

When  $v^r f < 5$ :

$$P_{\min \bullet kt} = 0.028(v^r f)^2 - 0.126v^r f + 1.02 \text{ MPa}$$

When  $5 < v^r f < 8$ :

$$P_{\min \bullet kt} = 0.411(v^r f)^3 - 7.37(v^r f)^2 + 44.7v^r f - 89.5 \text{ MPa}$$

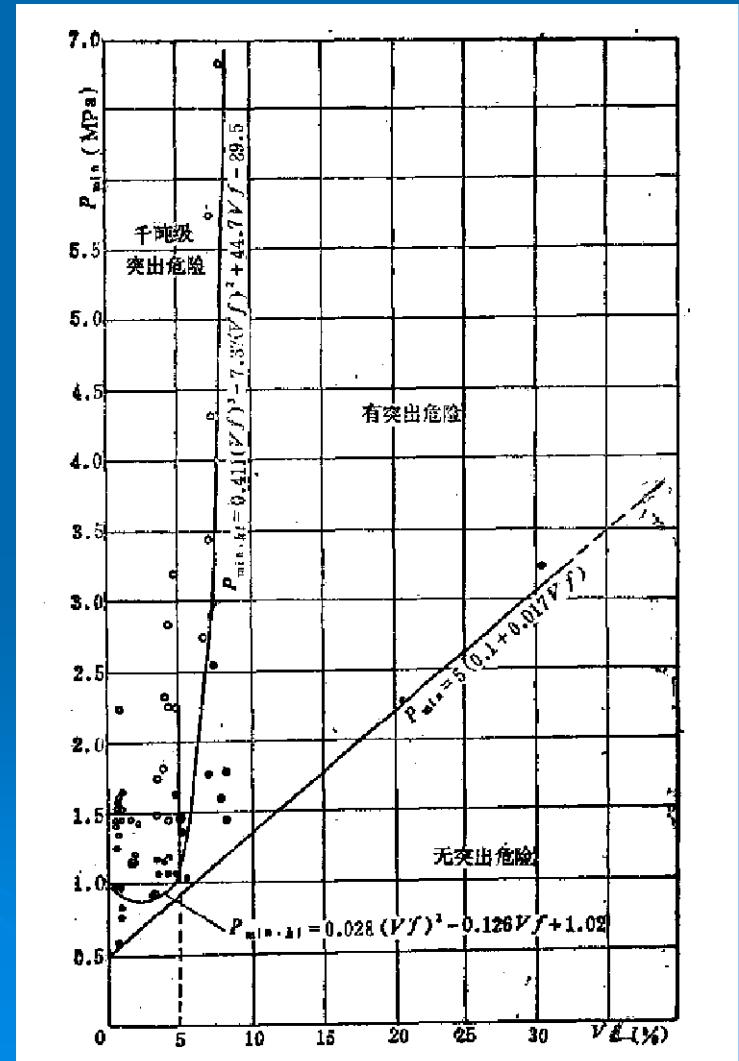
OB  
larger  
than  
1000t

# 5 RESEARCH STATUS

## 2 Regional OB Prediction method

**Minimum gas pressure  
of OB occurrence**

- statistical data of 26 mining areas in China





## 5 RESEARCH STATUS

### 2 Regional OB Prediction method

#### Detection techniques of geological structures

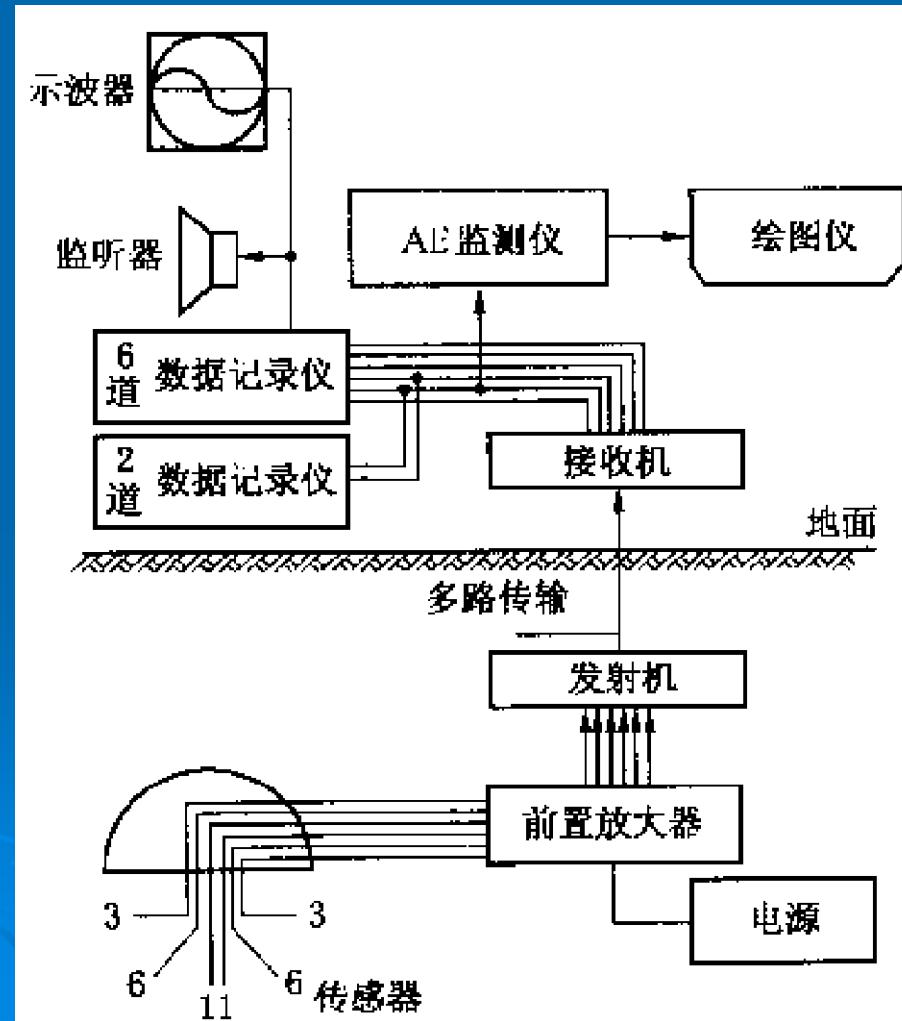
- **radio wave**
- **seismic**
- **geological radar**
- **Pulse ultrasound**

# 5 RESEARCH STATUS

## 3 Working face OB prediction

### Acoustic Emission method

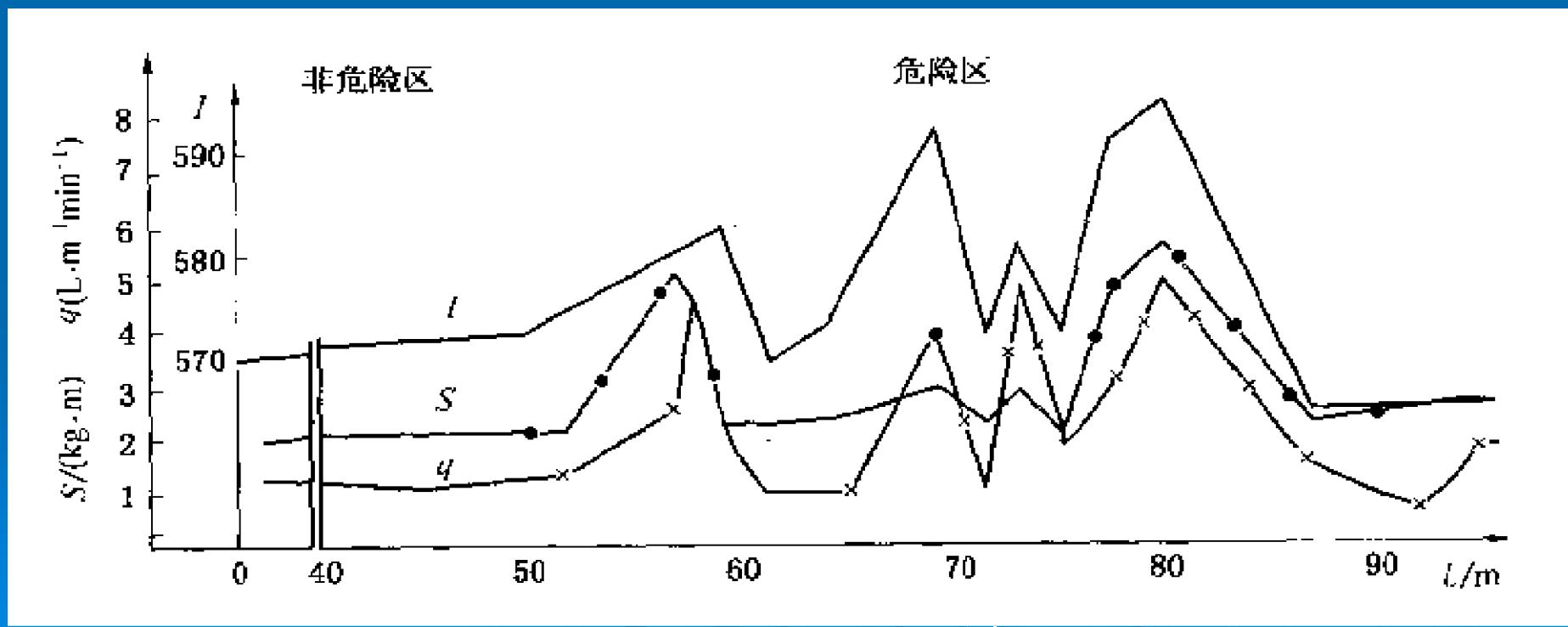
- In Nantong Coal Mine, the total AE events larger than 15 and its energy larger than 300 in 30 minutes after shotfiring are determined as the threshold values of OB.



# 5 RESEARCH STATUS

## 3 Working face OB prediction

EmE (Electromagnetic Energy) radiation monitoring method



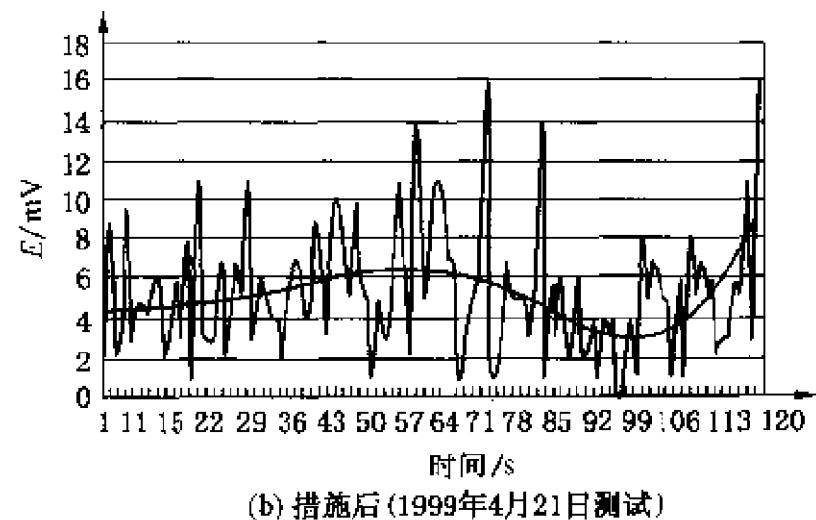
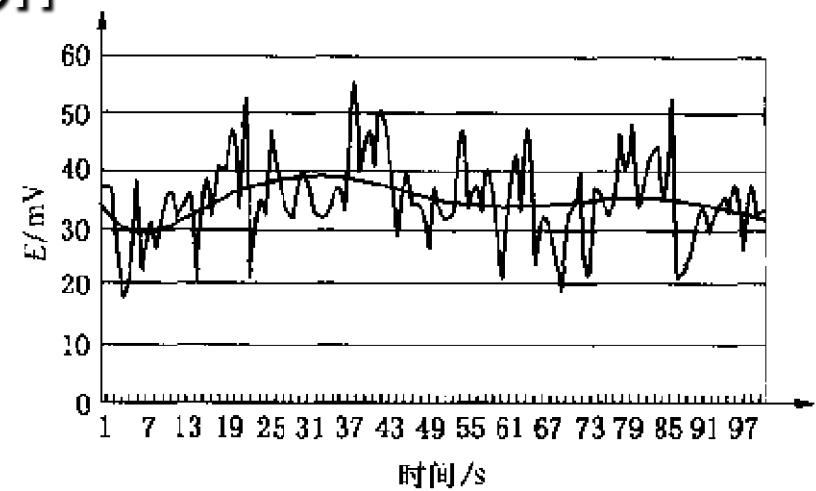
Measurement of EmE, S and q during tunnelling

# 5 RESEARCH STATUS

## 3 Working face OB prediction

**EmE (Electromagnetic Energy) radiation monitoring method**

- When there is OB risk, EmE and its pulse number are higher (Fig. a)





## 5 RESEARCH STATUS

### 3 Working face OB prediction

$V_{30}$  ( $V_{60}$ ) and  $K_v$  Indices

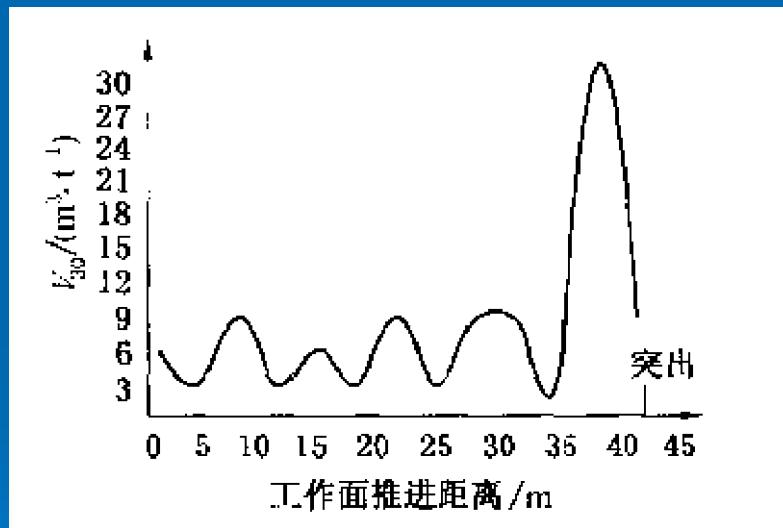
- The quantity of gas emission per ton coal in 30 (or 60) minutes after shotfiring:  $V_{30}$  ( $V_{60}$ )
  
- The variation coefficient of gas emission in 30 (or 60) minutes after shotfiring:  $K_v$

$$K_v = \frac{1}{Q} \sqrt{\frac{1}{n-1} \sum_{i=1}^n (Q_i - Q)^2}$$

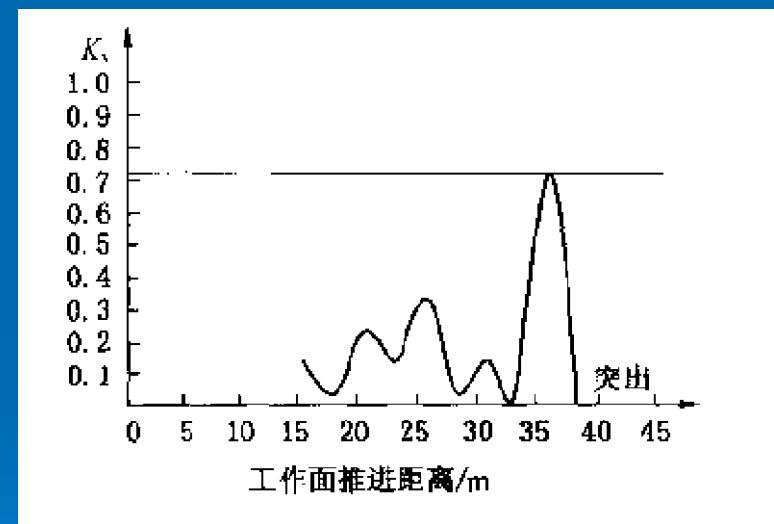
# 5 RESEARCH STATUS

## 3 Working face OB prediction

$V_{30}$  ( $V_{60}$ ) and  $K_v$  Indices



$V_{30}$  curve before OB occurrence



$K_v$  curve before OB occurrence

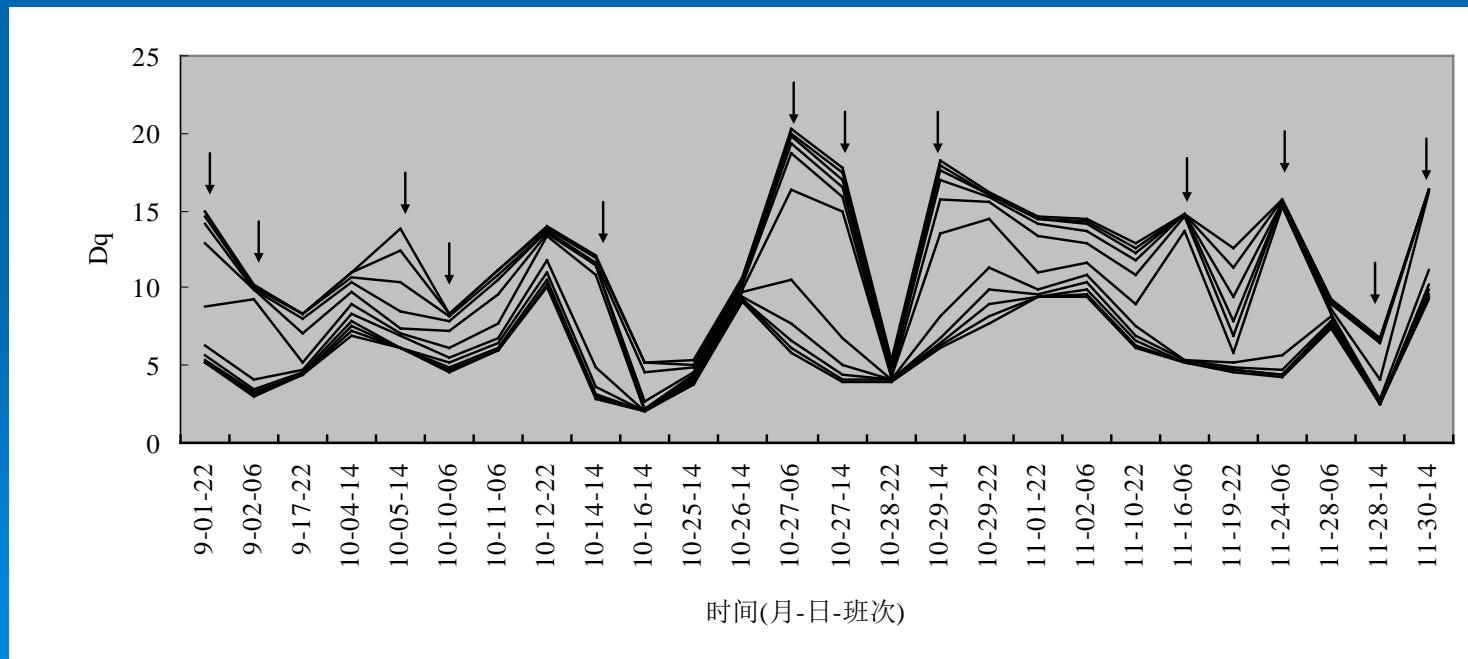
When  $V_{30} > 9 \text{ m}^3/\text{t}$  or  $K_v > 0.72$ , there is OB risk 2 ~ 5 m ahead of the face.

# 5 RESEARCH STATUS

## 3 Working face OB prediction

### Nonlinear characteristics of face gas emission

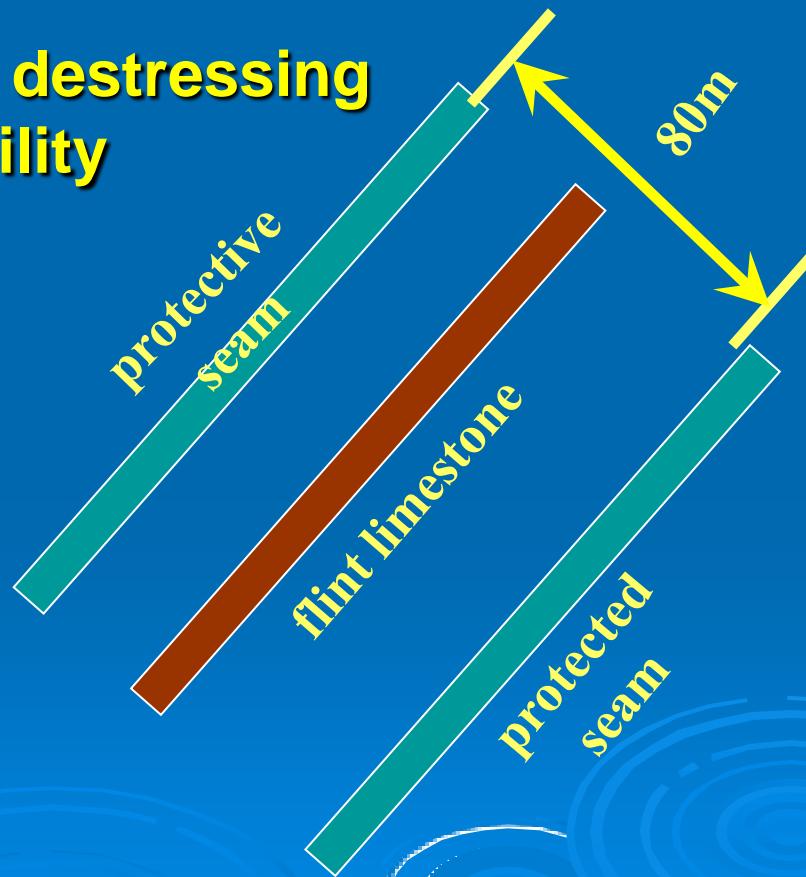
When there is OB risk, the multi-fractal spectra of face gas emission dehisce obviously.



# 5 RESEARCH STATUS

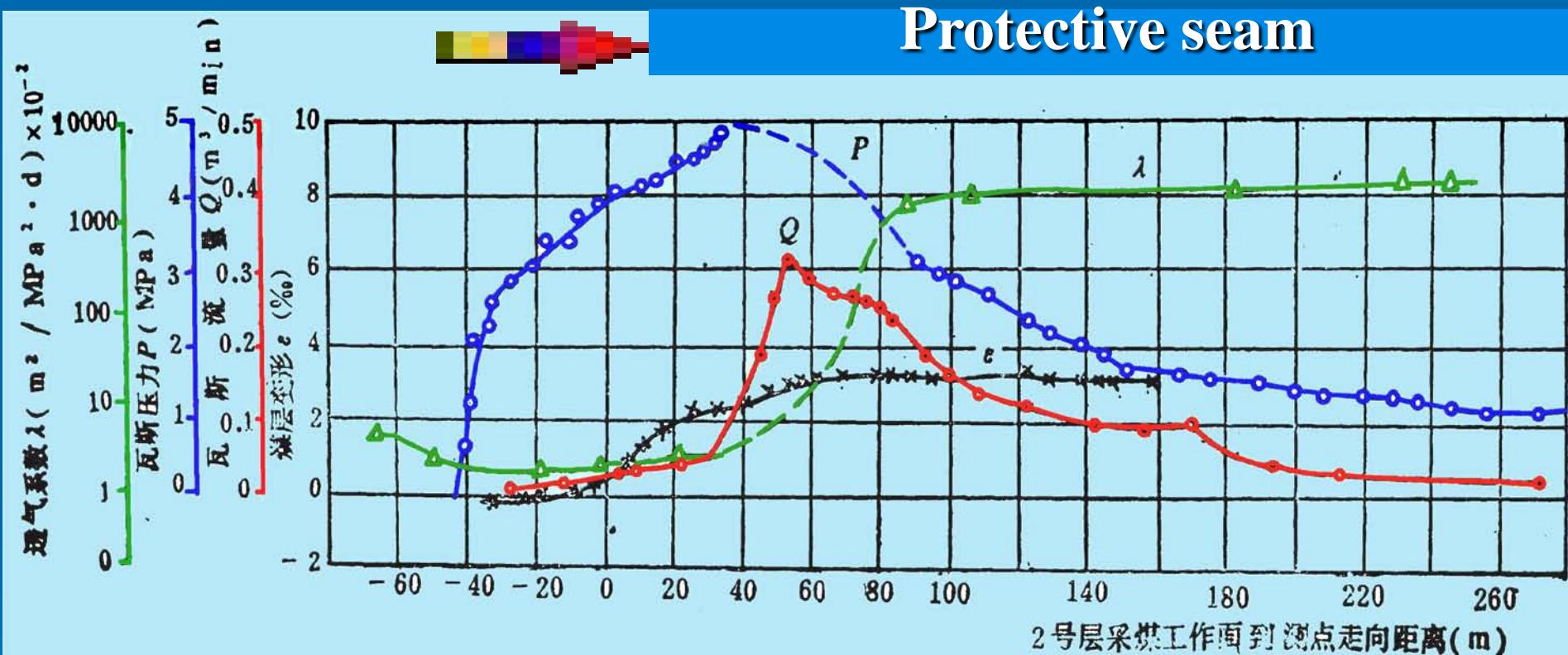
## 4 Regional OB prevention technique

**Mining protective seam- destressing  
and increasing permeability**



**Diagram of protective seam mining in Tianfu Coal Mine**

# Mining protective seam- destressing and increasing permeability



protected seam

The effect of protective seam mining

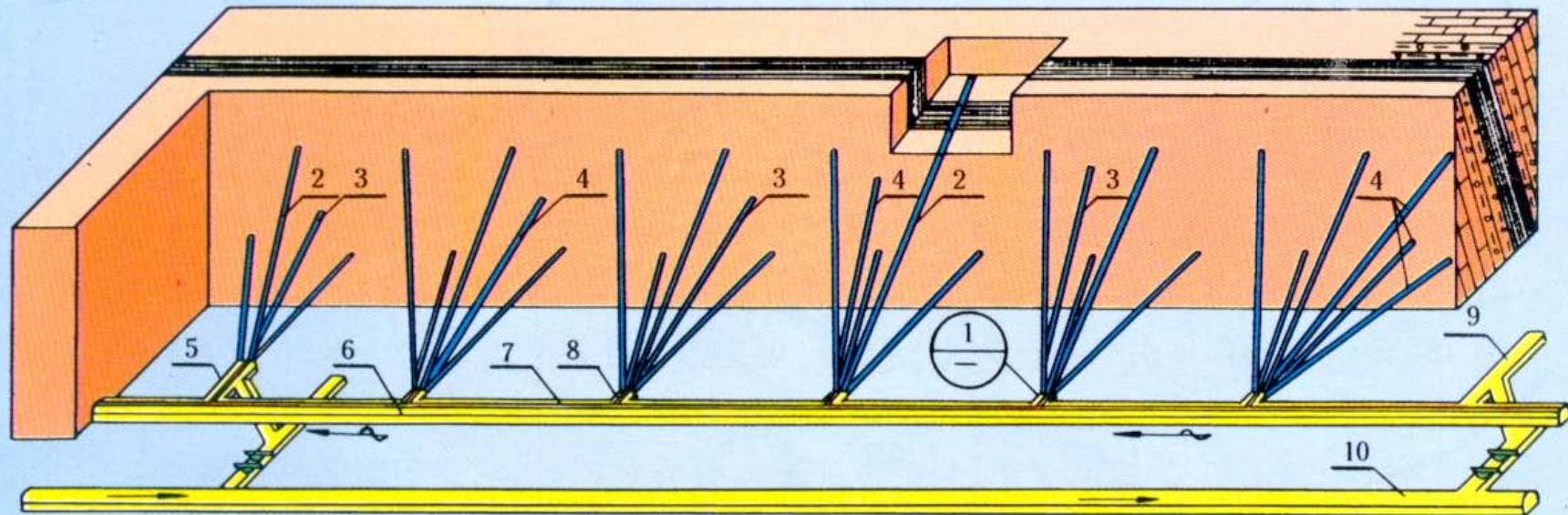
# 5 RESEARCH STATUS

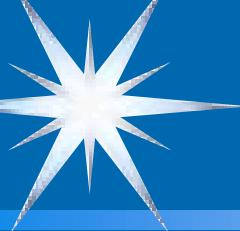
## 4 Regional OB prevention technique

Seam gas drainage in advance

大面积网格预抽瓦斯工程图

中梁山矿务局





# Gas drainage in advance – coal volume shrinks, stress reduces, permeability increases

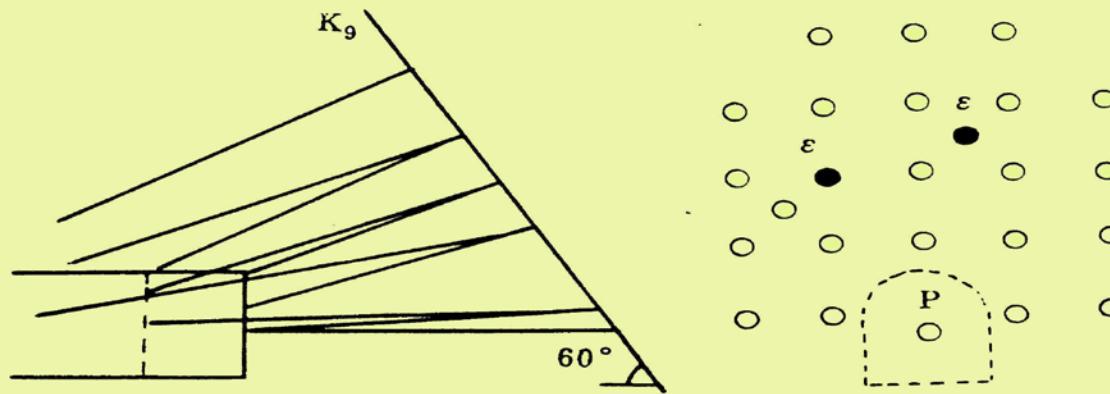


Fig. 2 The arrangement of boreholes at No. 9 crosscut

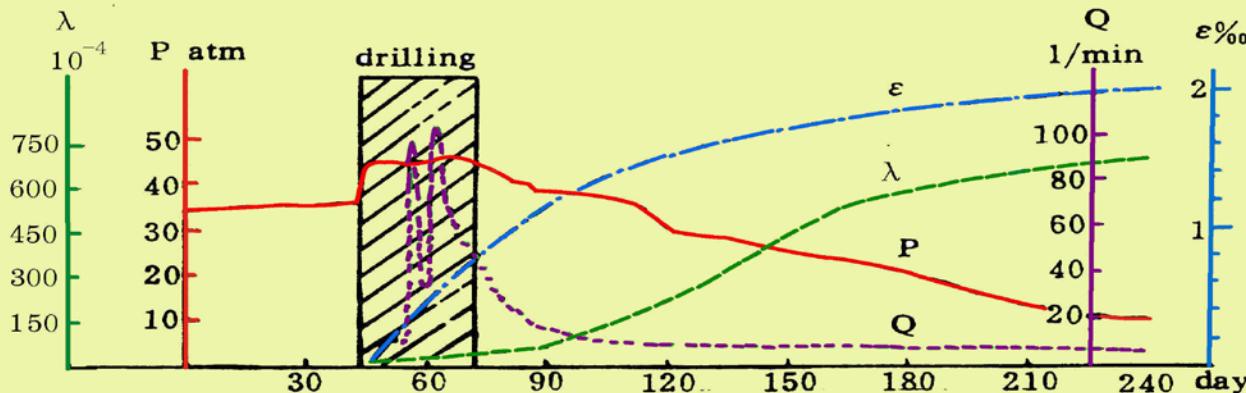


Fig. 3 The changing curves of several parameters during the degassing

# Gas drainage in advance – coal volume shrinks, stress reduces, permeability increases

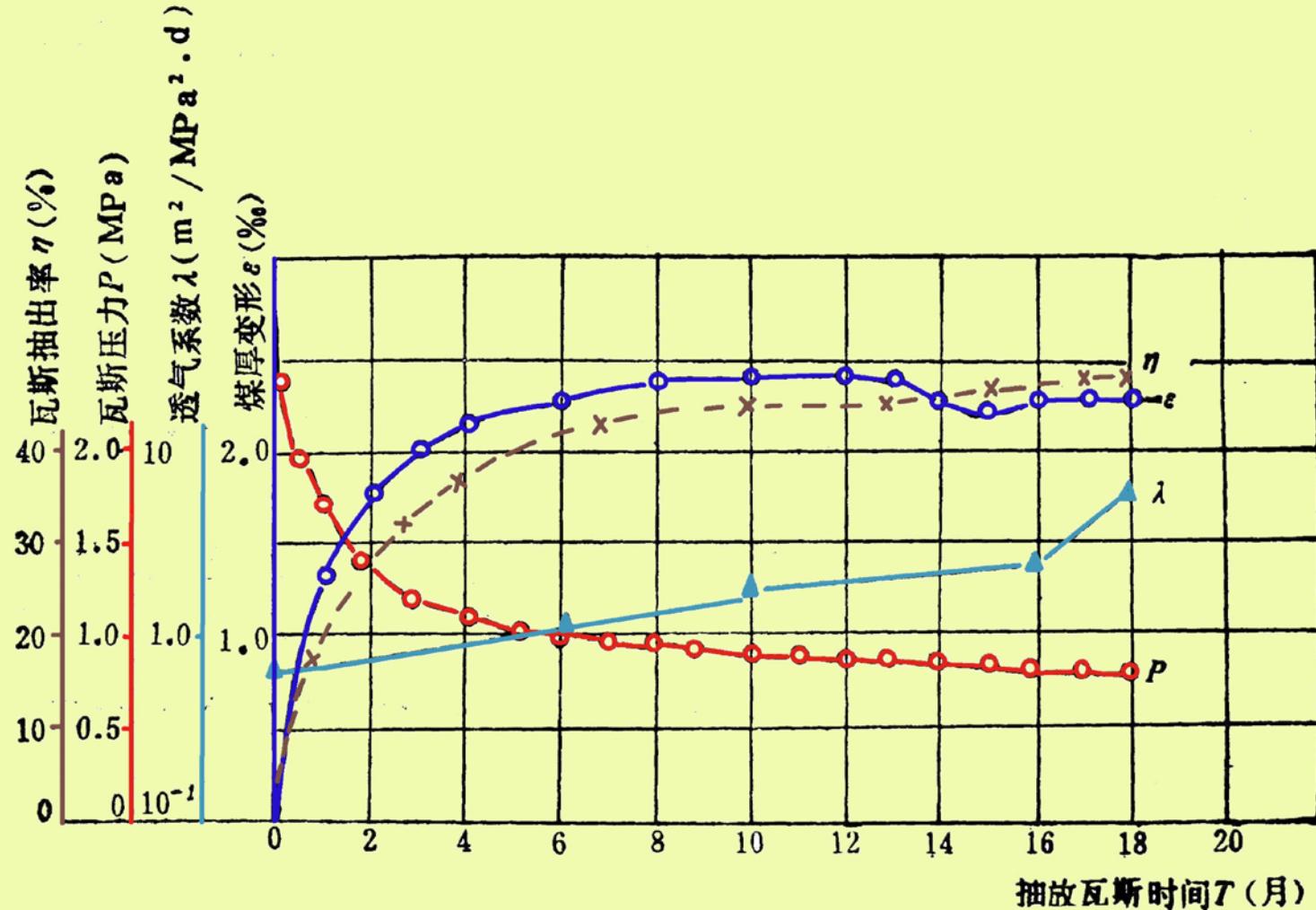


图 2 预抽 10 煤层瓦斯各参数随抽放时间的变化曲线

# 5 RESEARCH STATUS

## 5 Local OB prevention technique in coal/rock face

**Large diameter ( $\Phi 500$ ) destressing borehole in coal/rock face**

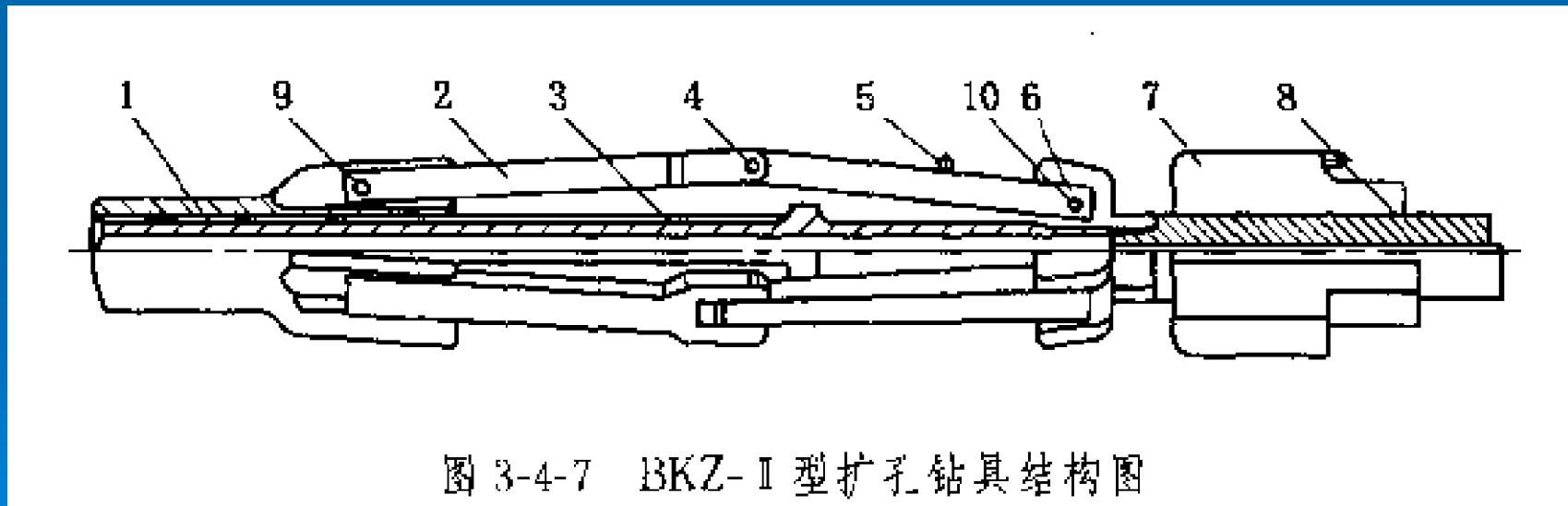
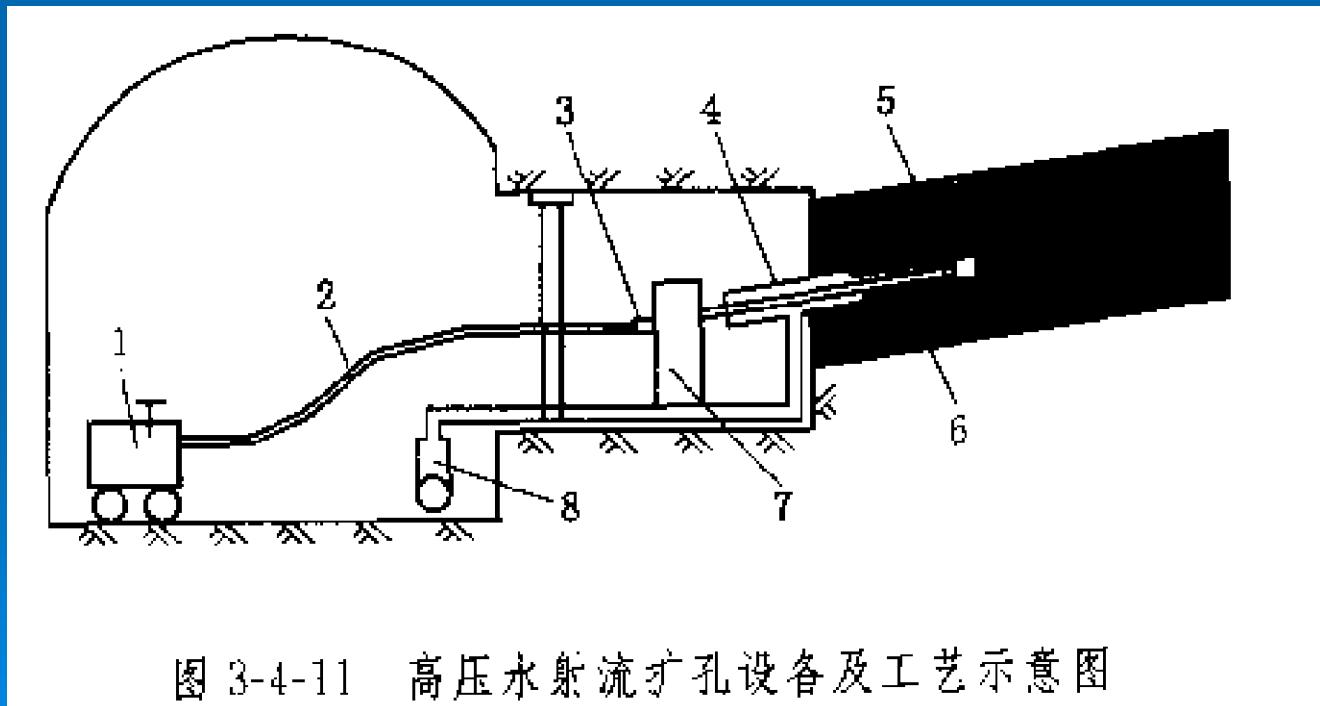


图 3-4-7 BKZ-II 型扩孔钻具结构图

## 5 RESEARCH STATUS

### 5 Local OB prevention technique in coal/rock face

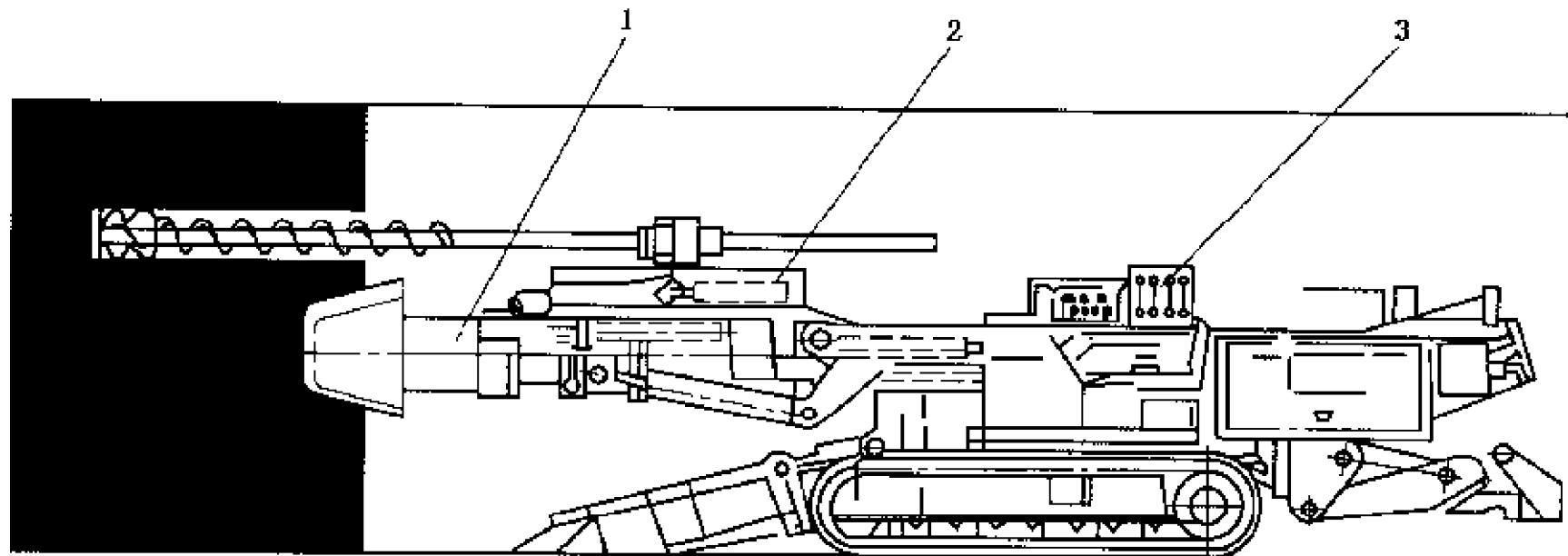
High pressure water injection for borehole enlarging



# 5 RESEARCH STATUS

## 5 Local OB prevention technique in coal/rock face

Drilling + extraction



# 5 RESEARCH STATUS

## 5 Local OB prevention technique in coal/rock face

### Slotting + Extraction

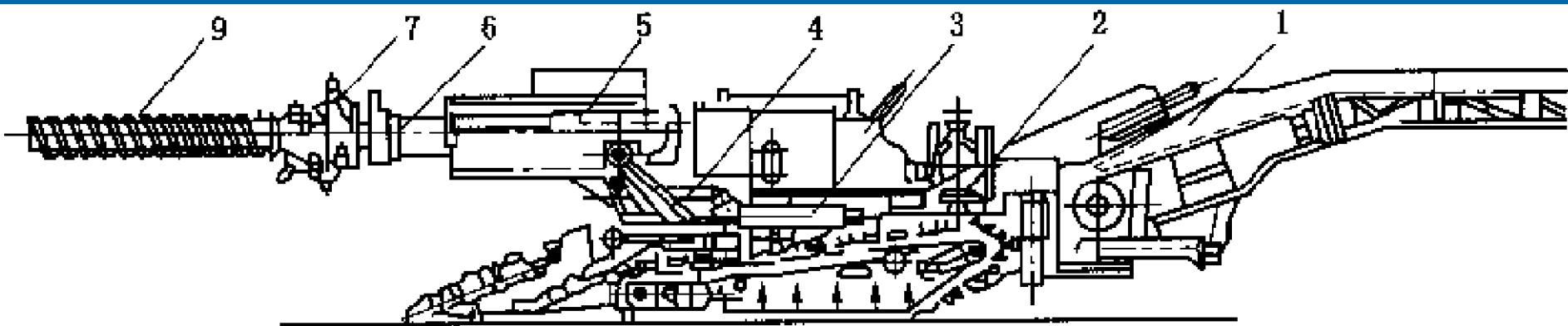


图 3-4-15 开卸压槽时掘进机工作状态

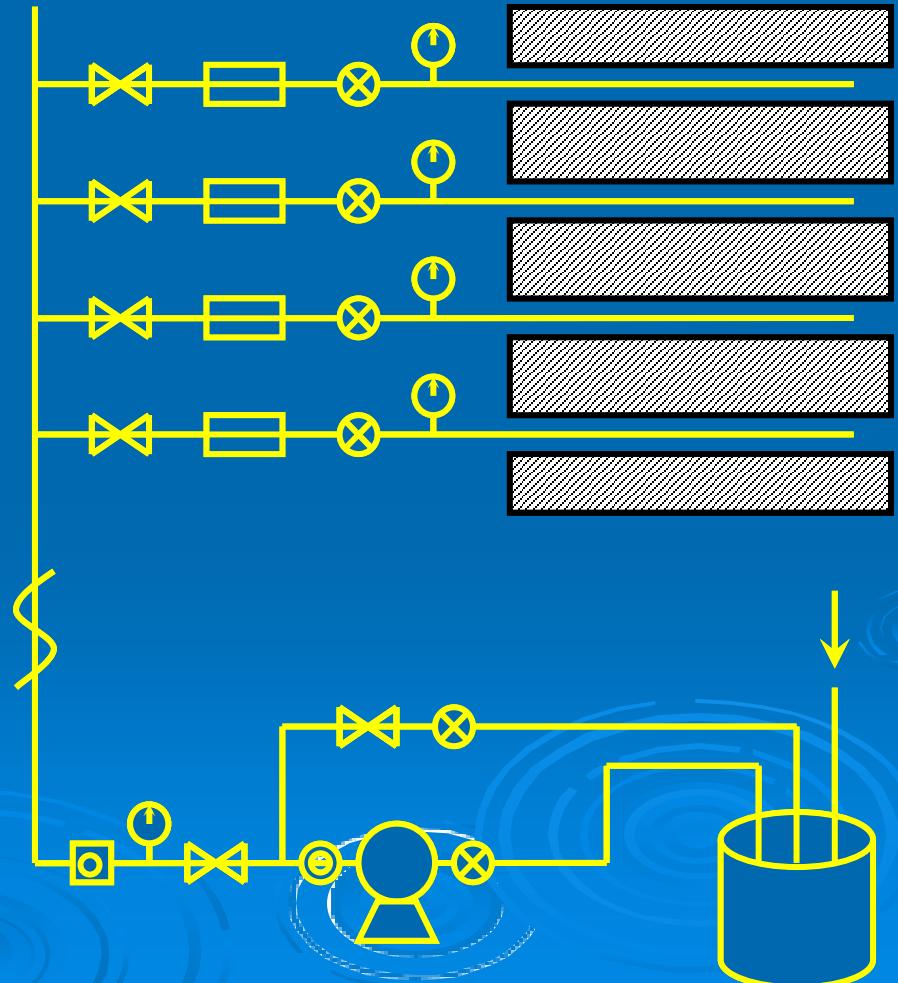
1—转载机构；2—司机座；3…水平回转油缸；4…升降油缸；5—推进油缸；  
6—工作臂；7—截割头；8 - 中心钻；9—开卸压槽装置

# 5 RESEARCH STATUS

## 5 Local OB prevention technique in cutting face

### Hydraulic destressing ahead of mining face

- The coal ahead of the face can be destressed and extruded out.
- the destressed zone ahead of the face can be enlarged.



# 6 KEY ISSUES

- 1 Low permeability coal seams – techniques to enhance permeability
- 2 In seam long hole drainage

## Key techniques:

Effectively remove cuttings

Directional drilling

Increase drilling power

Minimize outbursting while drilling



Increase borehole length

## 6 KEY ISSUES

### 3 Continuous monitoring techniques of OB precursors and OB risk identification techniques

Precursor: gas emission rate (from borehole or face), EmE, etc.

Identification: extracting characteristics, AI, etc.

### 4 Evolution of OB hazards and its minimizing techniques

The spread mechanism of OB shock wave and gas, its influence on mine ventilation system, the evolution pattern of secondary disasters.

# THANK YOU!

