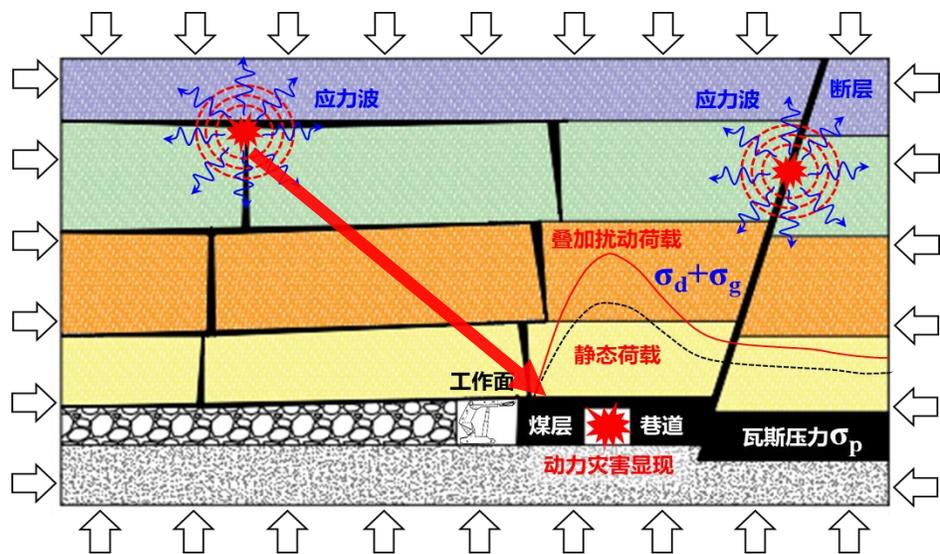


# 1

## 动静载叠加诱发冲击机理



- 动静载叠加诱冲力学模型
- 临界冲击应力的确定
- 动态应变率定义动静载
- 力、能的冲击矿压分类
- 动静载及其叠加作用效应

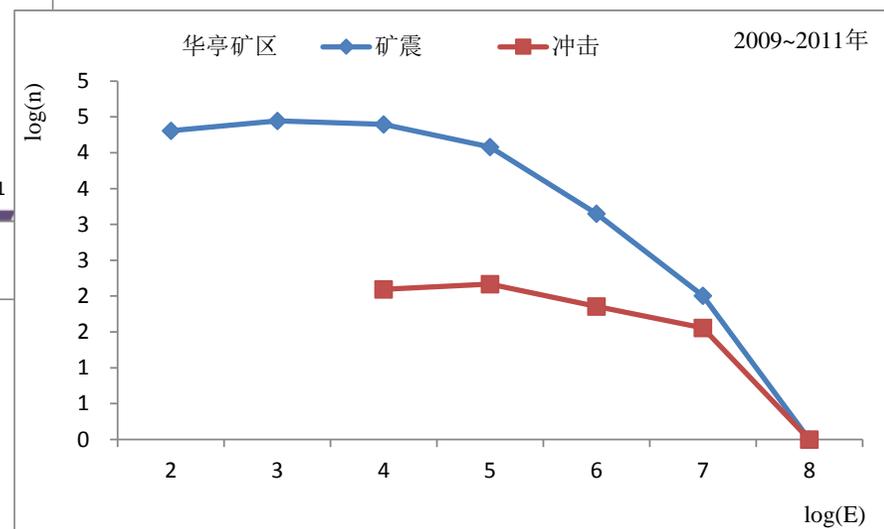
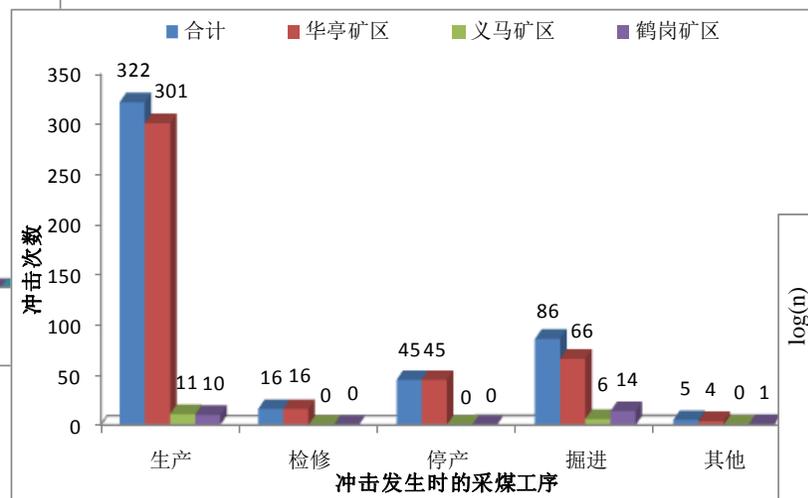
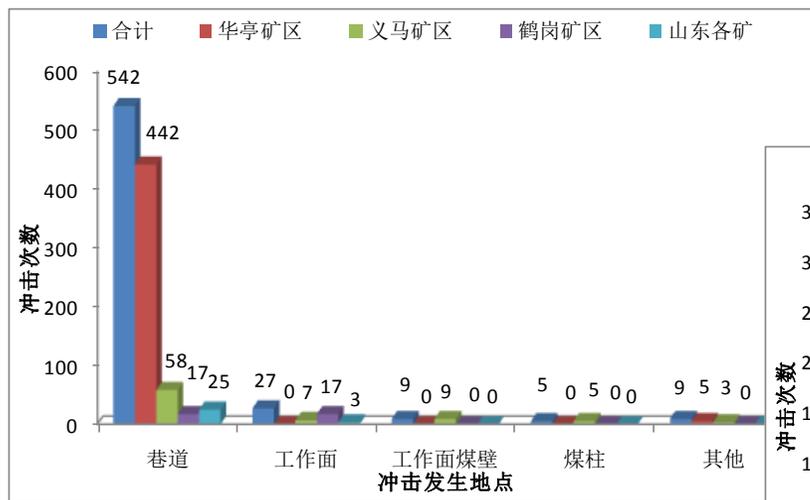
# 冲击矿压统计规律 (06-12)



State Key Laboratory  
of Coal Resources and Safe M



- 冲击主要发生在巷道，占91%；
- 冲击主要发生在采煤和掘进工序中，分别为322次和86次。占86%；
- 华亭矿区矿震和冲击矿压频次 $n$ 与能量 $E$ 之间的关系。



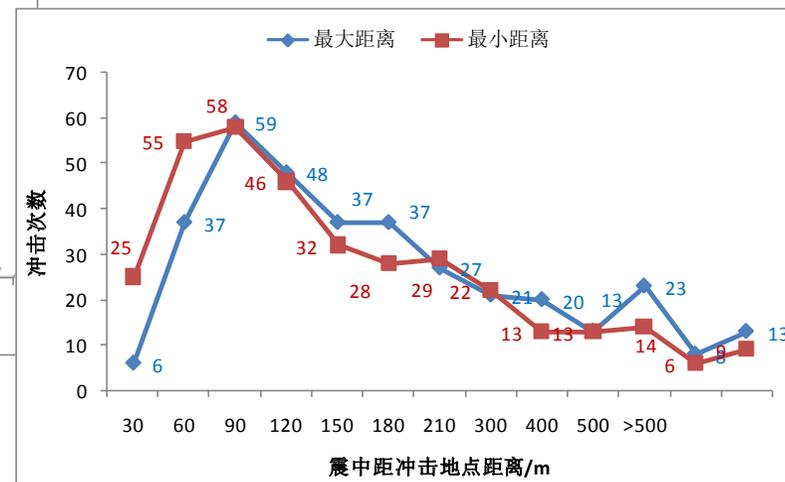
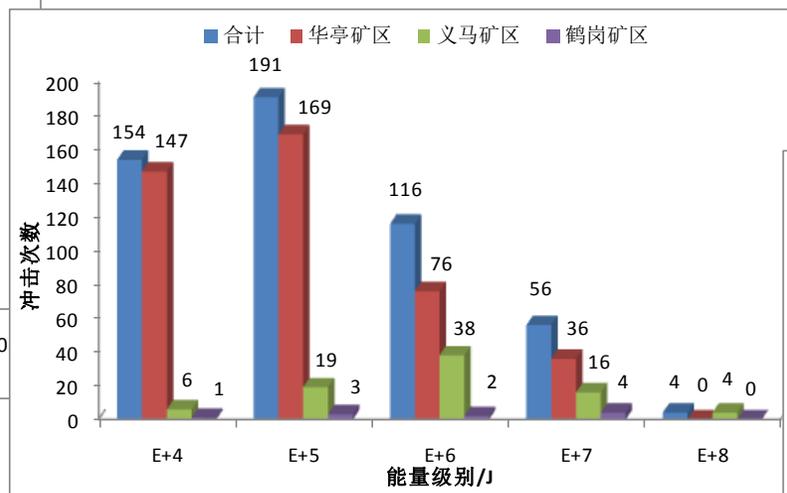
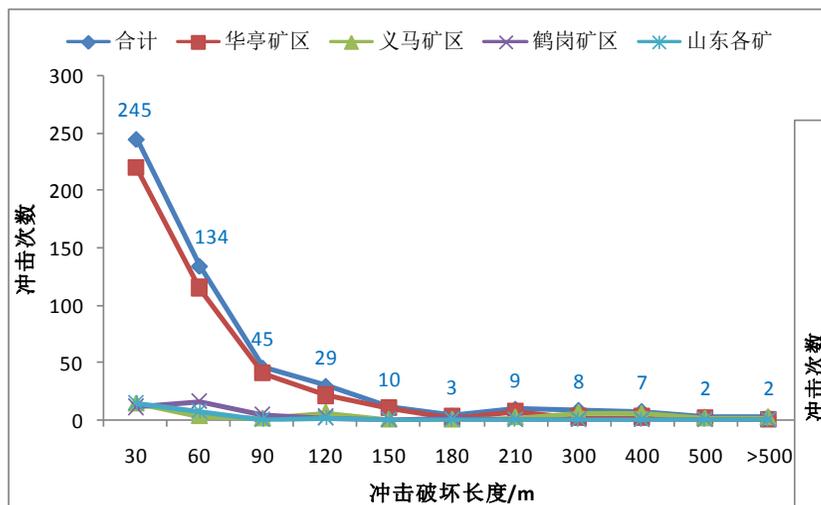
# 冲击矿压统计规律 (06-12)



State Key Laboratory  
of Coal Resources and Safe M



- 冲击破坏长度主要在90m范围以内;
- 冲击能量主要: E4-E6J。其中华亭主要为E4-E5J, 义马主要为E6J。义马矿区有4次E8J的冲击;
- 震中距冲击地点最小距离主要分布在150m范围以内。



# 动静载叠加诱冲力学模型



State Key Laboratory  
of Coal Resources and Safe M

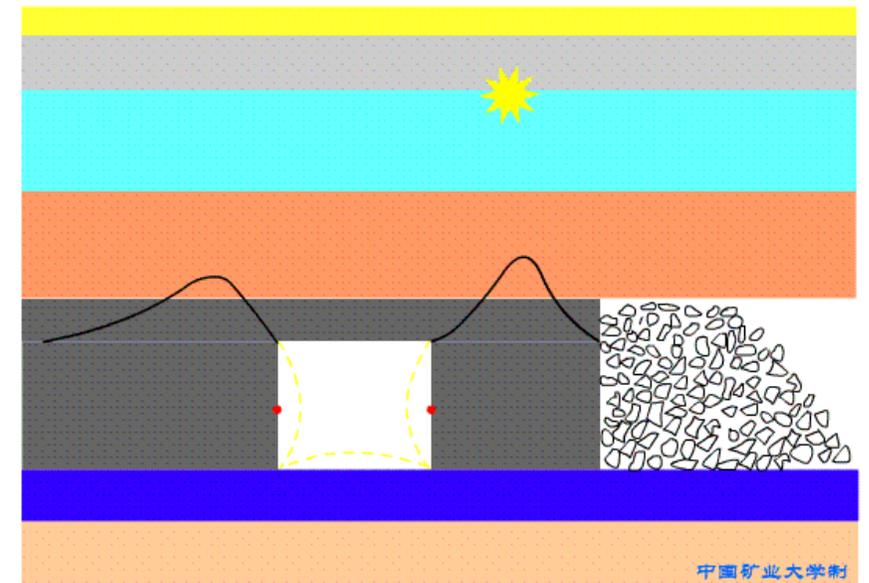
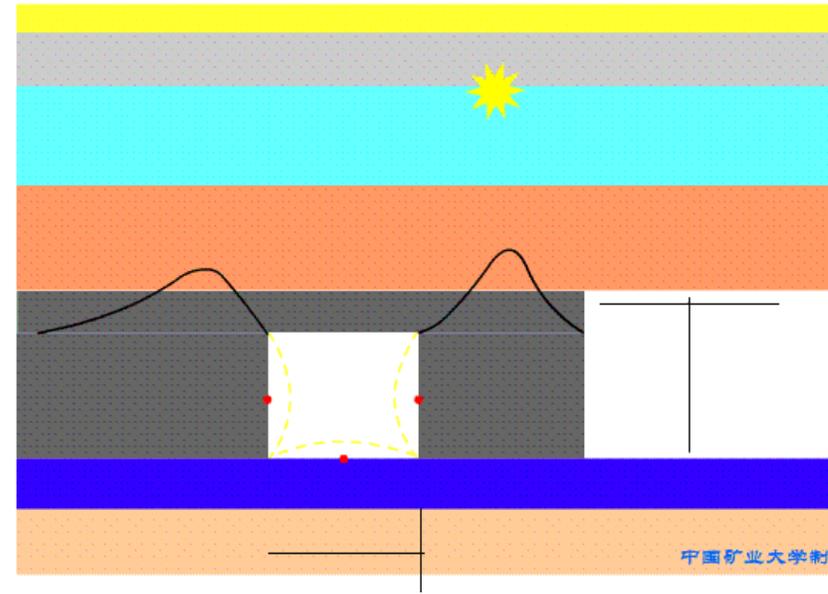
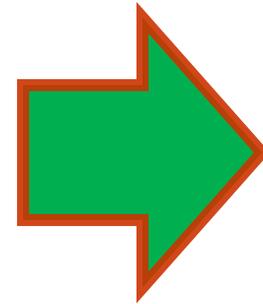
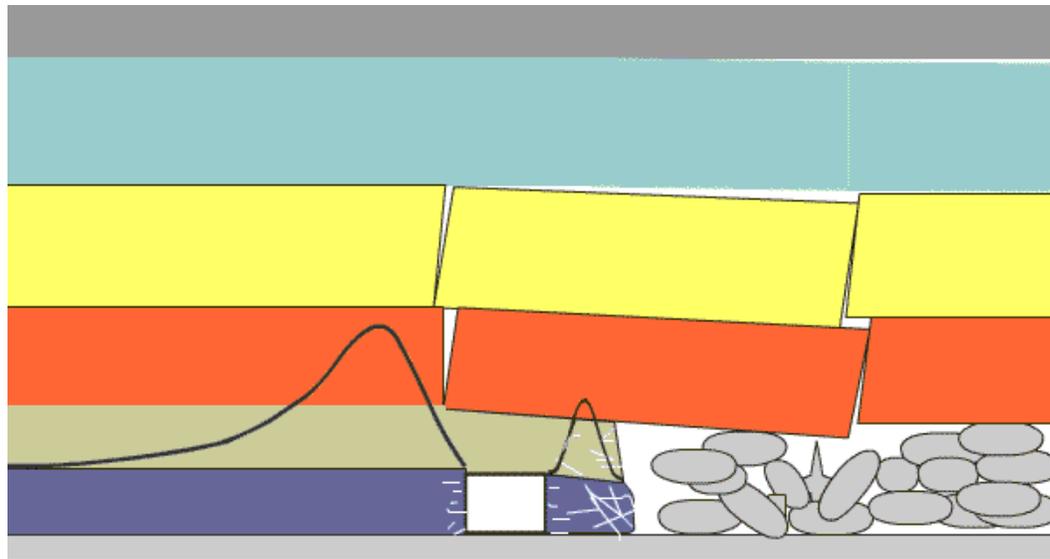


## 冲击的能量条件

$$\frac{dU_R}{dt} + \frac{dU_C}{dt} + \frac{dU_S}{dt} > \frac{dU_B}{dt}$$

## 冲击的应力条件-动静载

$$\sigma_j + \sigma_d \geq \sigma_{b \min}$$



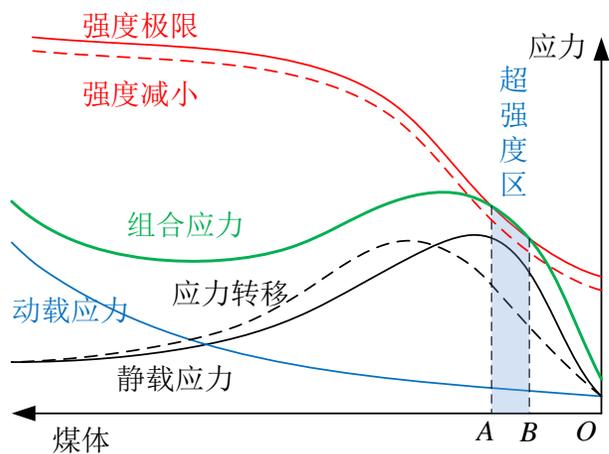
## 动静载叠加诱发冲击动力灾害机理

➤ 能量表达: 
$$\frac{dU_R}{dt} + \frac{dU_C}{dt} + \frac{dU_S}{dt} > \frac{dU_B}{dt}$$

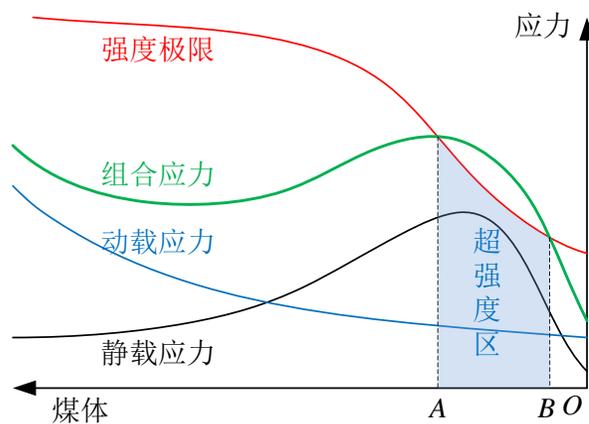
➤ 单向: 
$$U = \frac{(\sigma_j + \sigma_d)^2}{2E} \quad U_{bmin} = \frac{\sigma_{bmin}^2}{2E}$$

$$\sigma_j + \sigma_d \geq \sigma_{bmin}$$

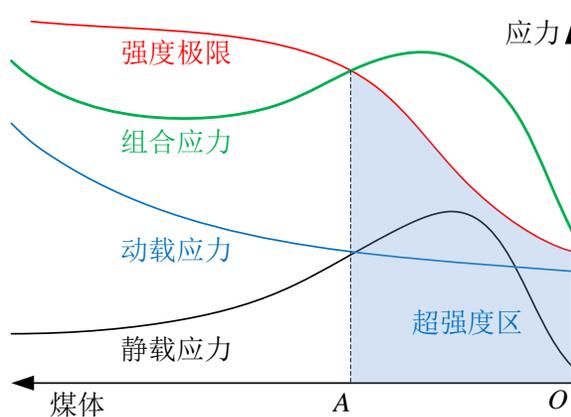
$U_R$ —围岩中储存的能量;  
 $U_C$ —煤体中储存的能量  
 $U_S$ —矿震能量;  
 $U_B$ —冲击时消耗的能量  
 $U_{bmin}$ —动态破坏最小能量  
 $\sigma_j$ —静载应力  
 $\sigma_d$ —动载应力  
 $\sigma_{bmin}$ —临界应力



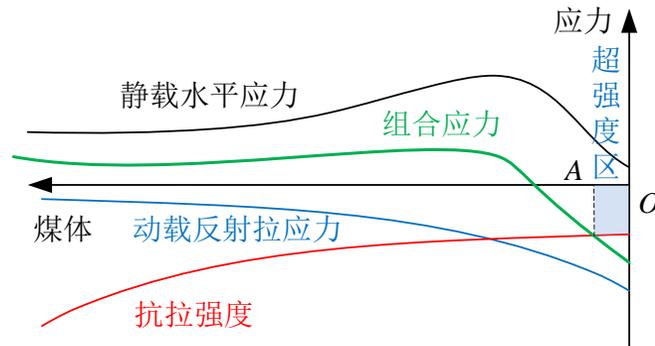
低应力扰动



动载扰动

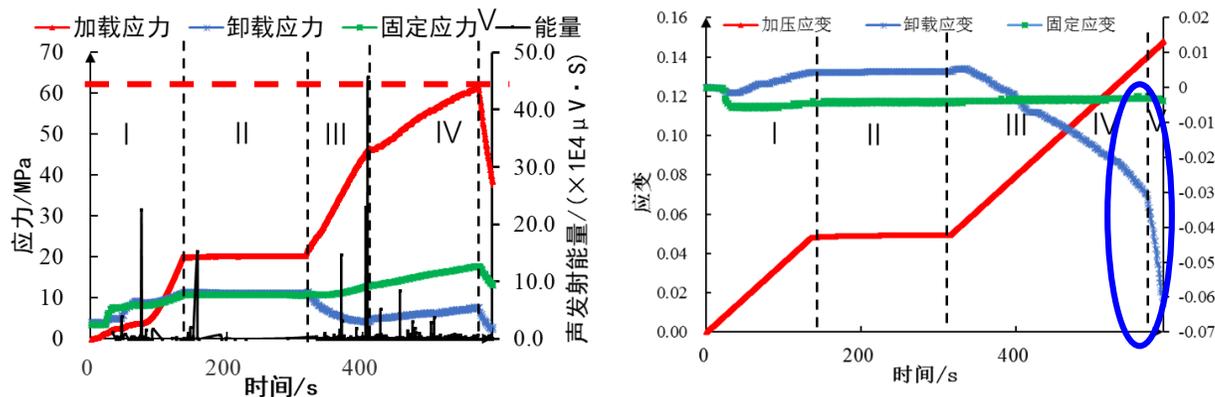


动静组合



反射拉伸

## “加-卸” 路径下煤样冲击临界值



### 冲击需要满足两个条件

- 卸载速率条件:

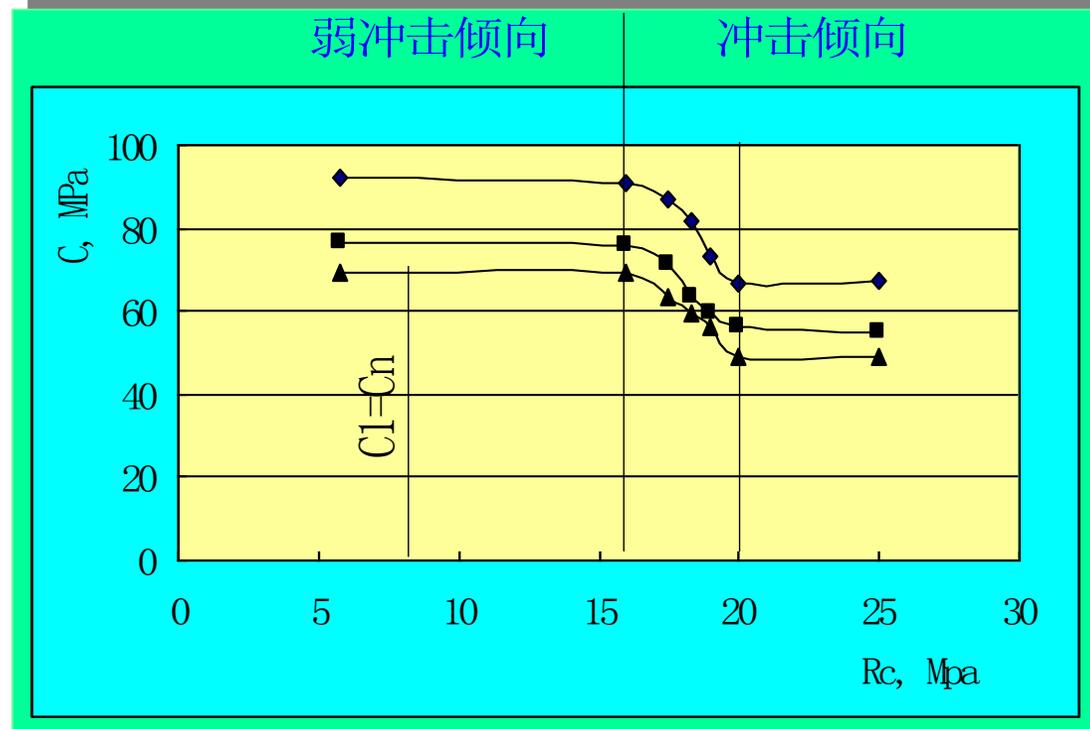
<1.128mm/min , 未冲击

>2.77mm/min , 冲击

- 应力条件:

<60MPa , 未冲击

>60MPa , 冲击



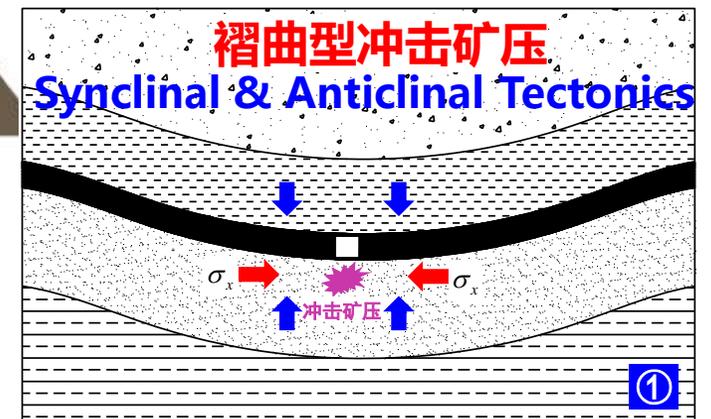
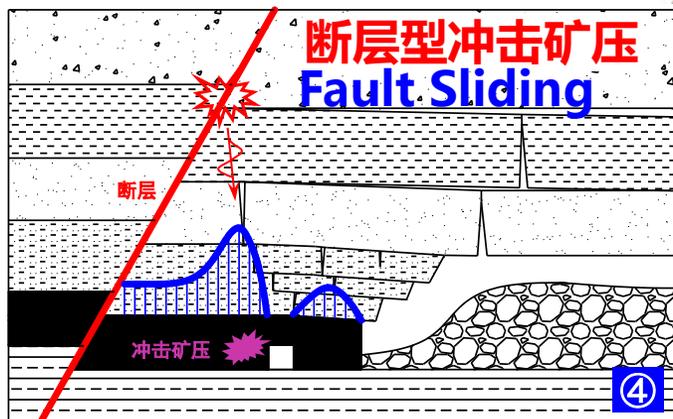
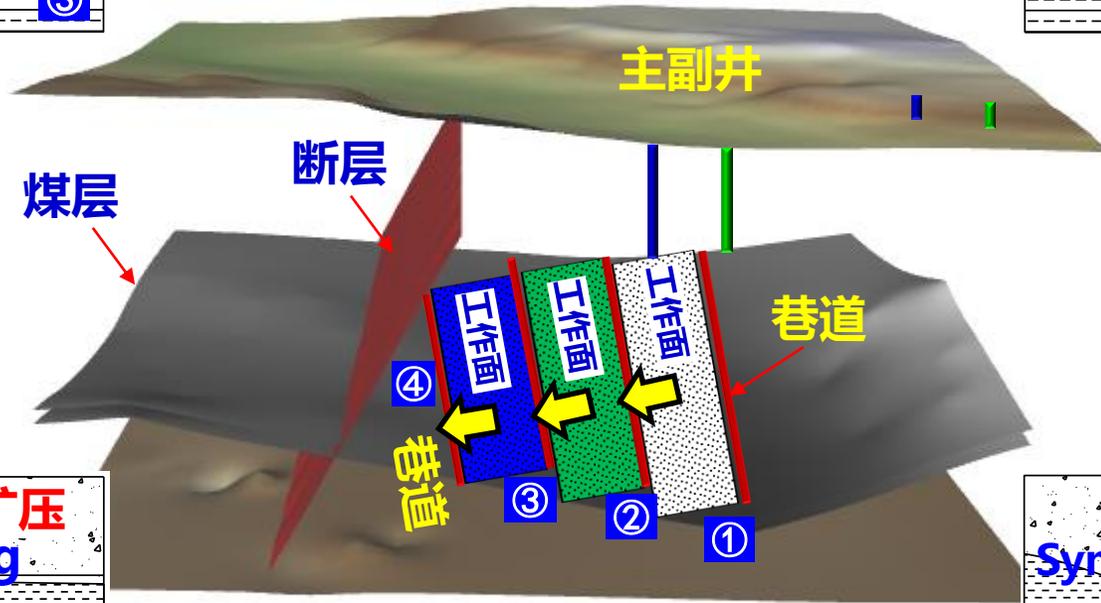
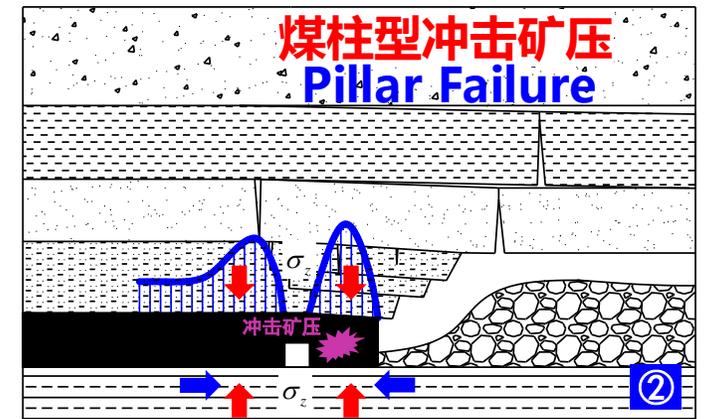
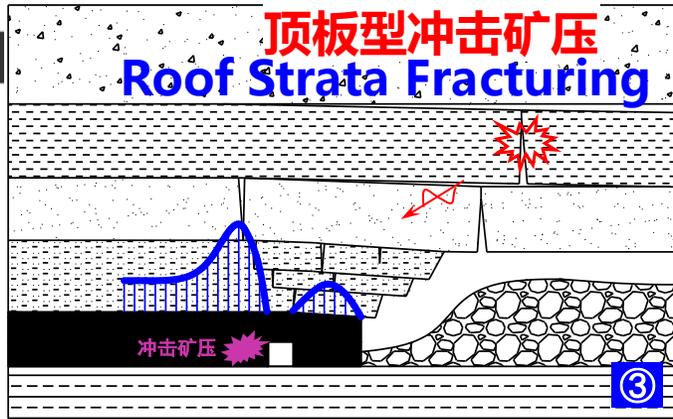
- **静载、动载的定义：**
- **动态应变率：单位时间的应变量**
  - **煤岩动力学实验：应变率大于 $10^{-3}/s$ 时，煤岩破坏与应变率具有较强的相关性；**
  - **煤矿矿震动载：震源载荷应变率在 $10^{-3} \sim 10^{-1}s^{-1}$ 级之间。**

| 应变率/ $s^{-1}$          | 载荷状态 | 载荷变化率/(MPa/s) | 应力变化规律 |
|------------------------|------|---------------|--------|
| $<10^{-5}$             | 静载   | $<0.1$        | 基准载荷   |
| $10^{-5} \sim 10^{-3}$ | 应力扰动 | $0.1 \sim 10$ | 应力扰动   |
| $>10^{-3}$             | 动载   | $>10$         | 动态变化   |

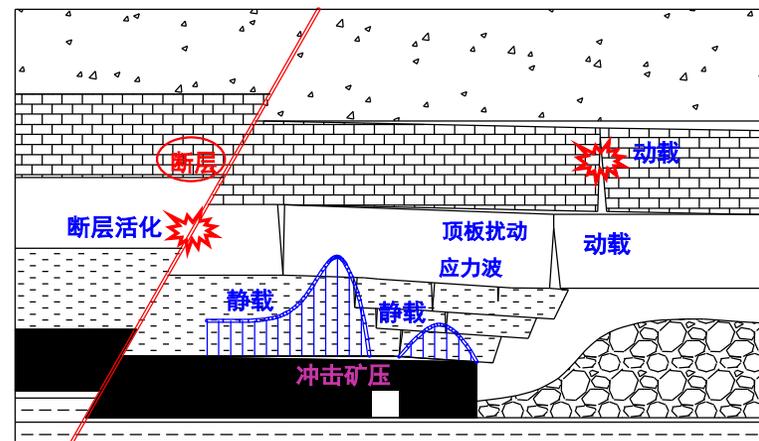
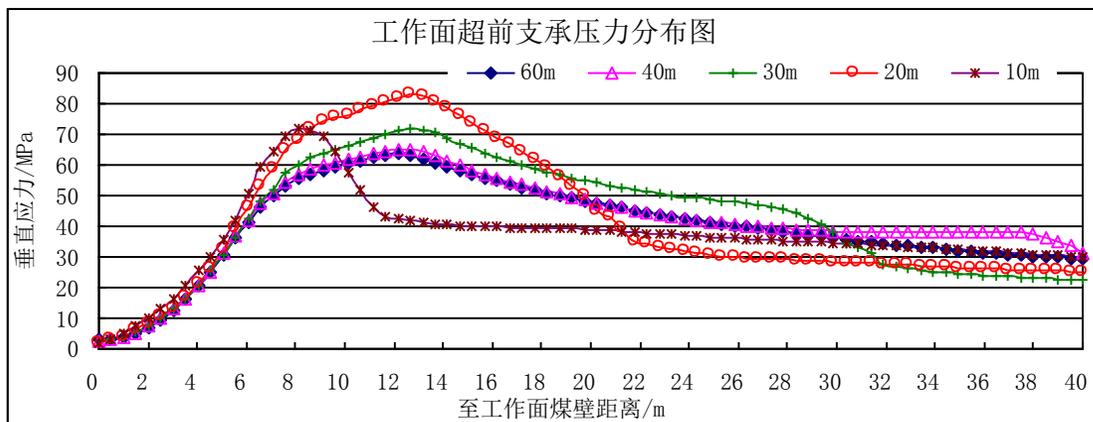


# 冲击矿压类型

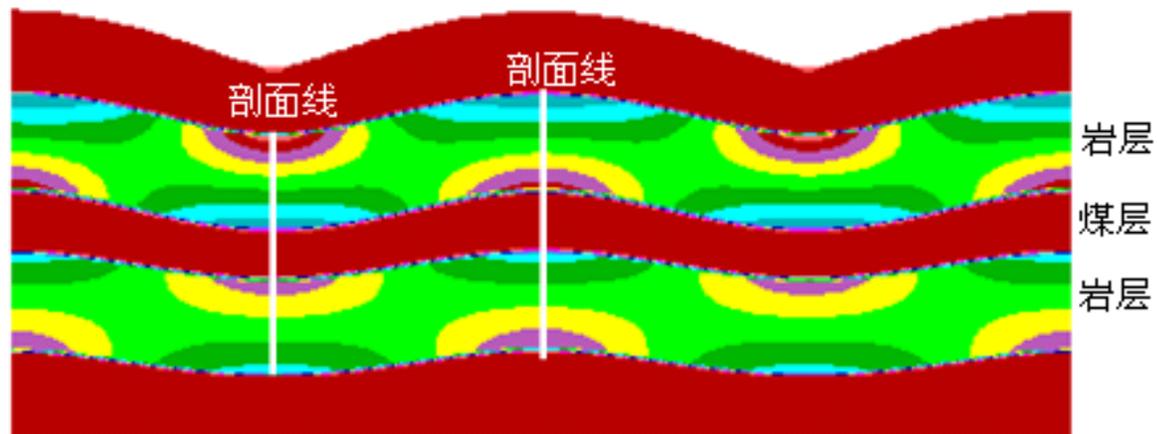
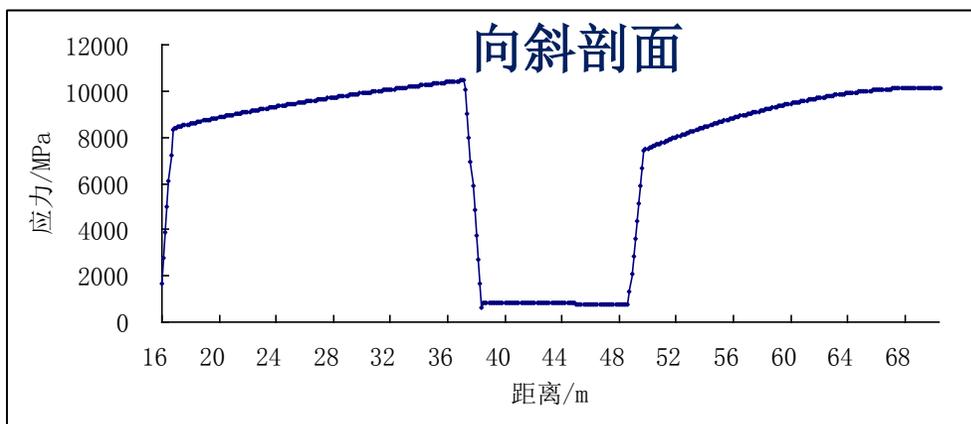
## Classification of Coalburst



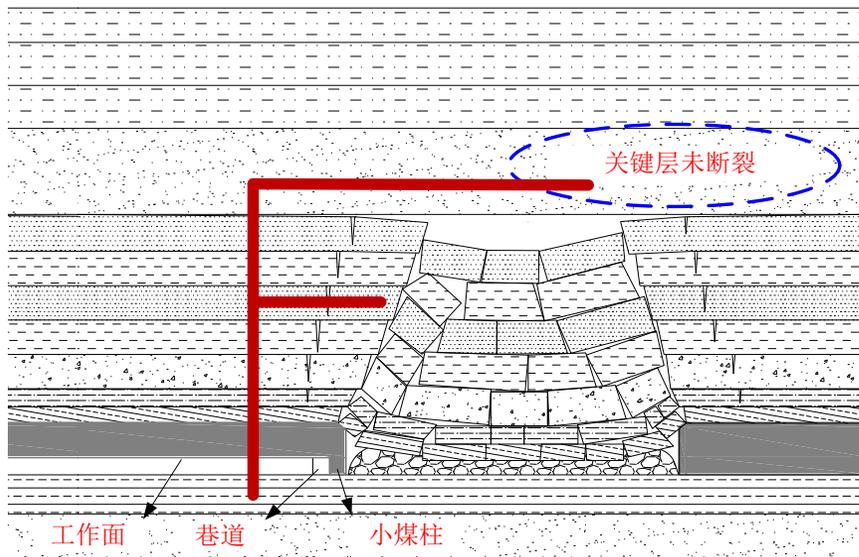
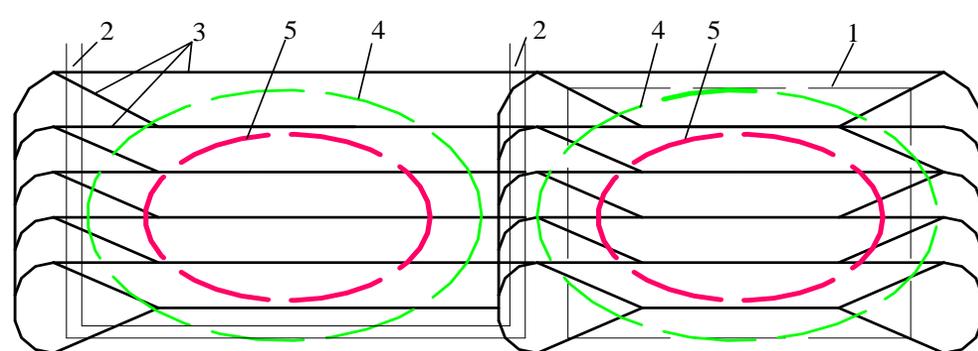
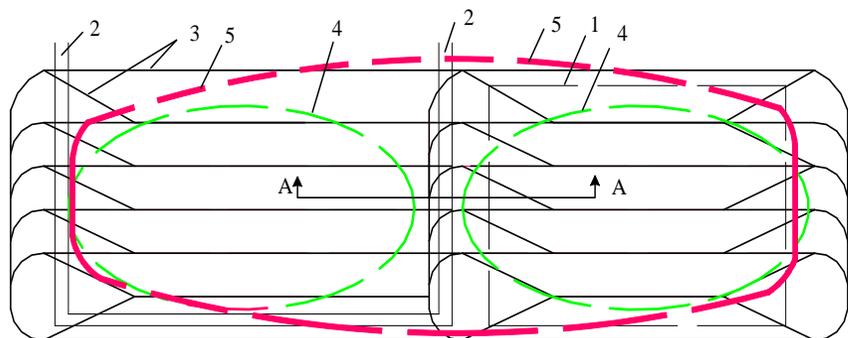
## □ 断层附近的冲击规律



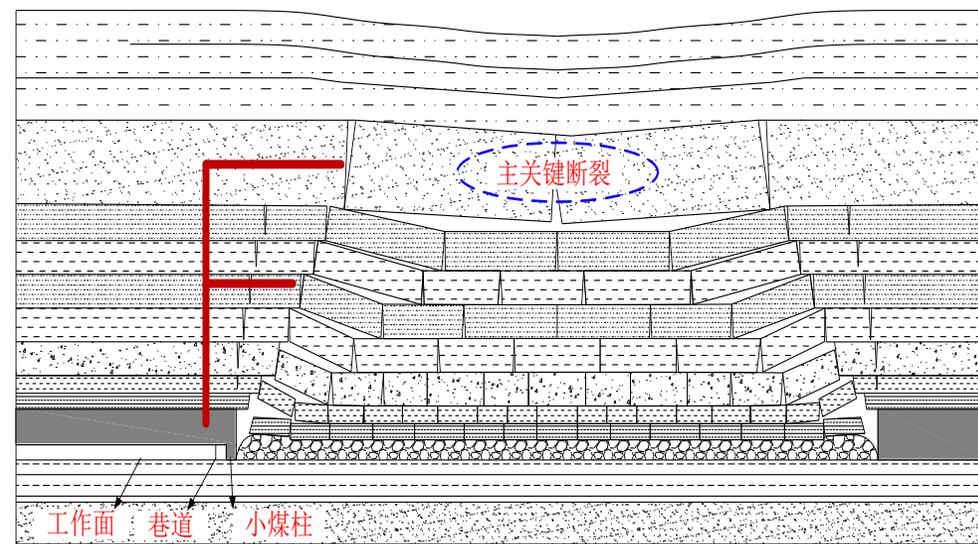
## □ 褶皱构造附近的冲击规律



## ➤ 覆岩的 ⊗ —Π—F—T 型结构 (2012年)



### 长臂F型结构



### 短臂F型结构

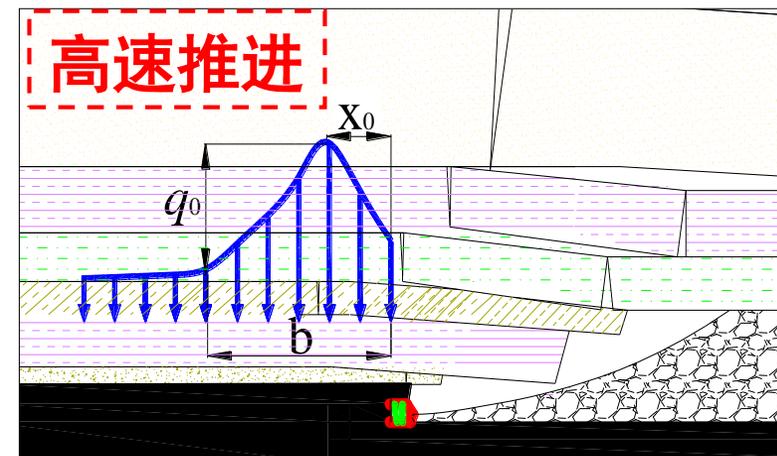
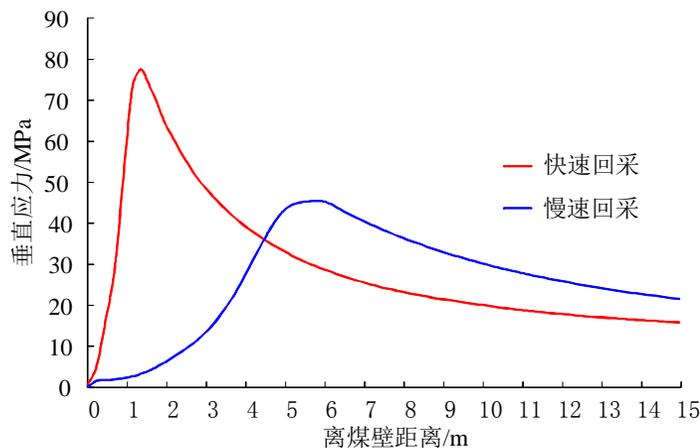
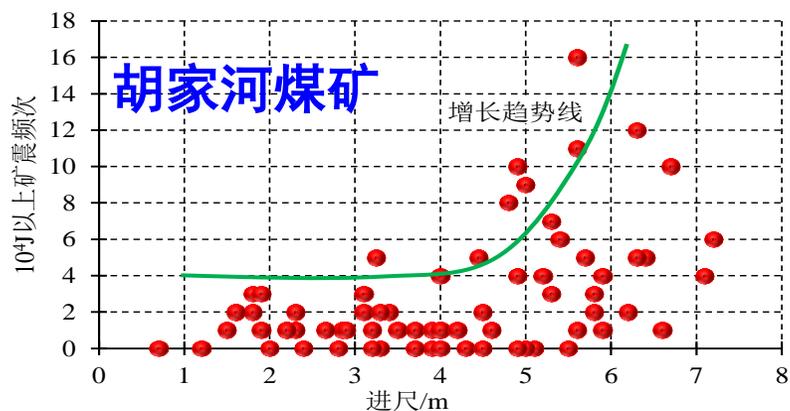
# 动静载及叠加作用效应



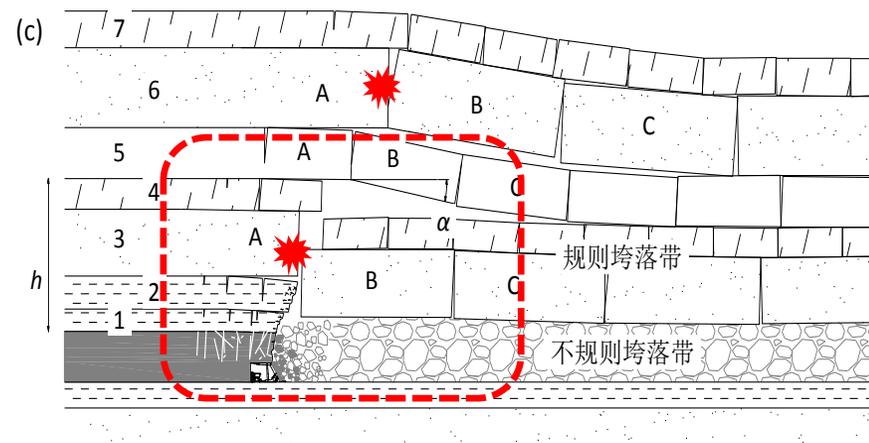
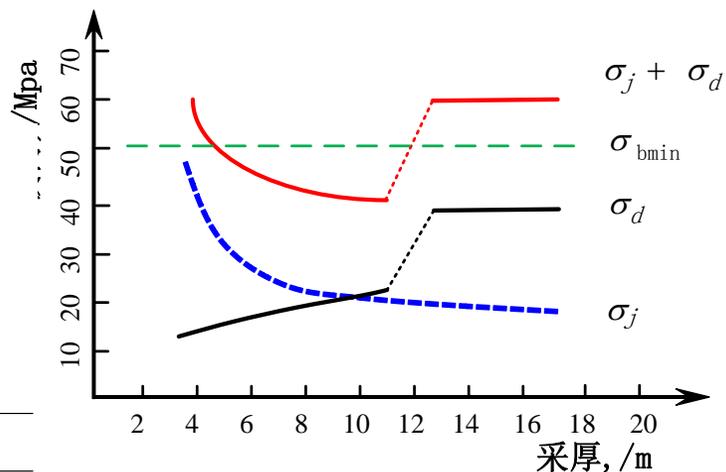
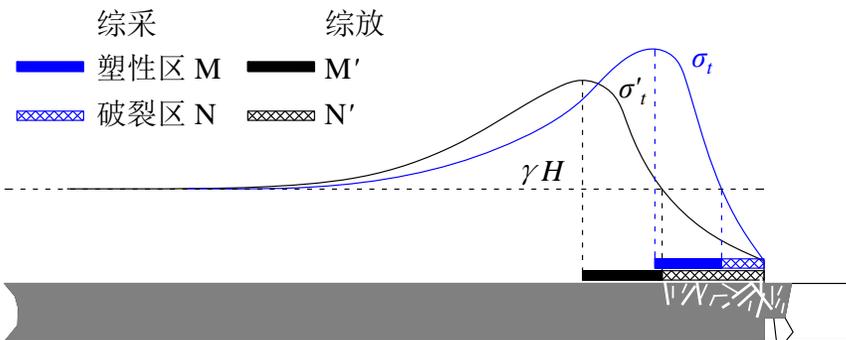
State Key Laboratory of Coal Resources and Safe M



## 回采速度对冲击的控制作用



## 综放的降载减冲效应(2016)

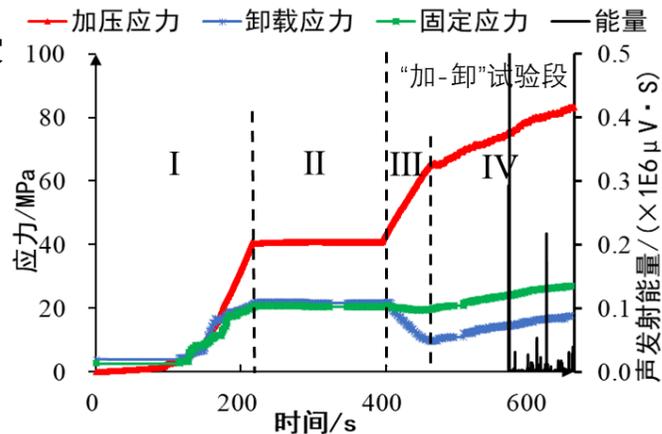


## ➤ 煤巷掘进应力路径转换及诱冲机制 (2019)

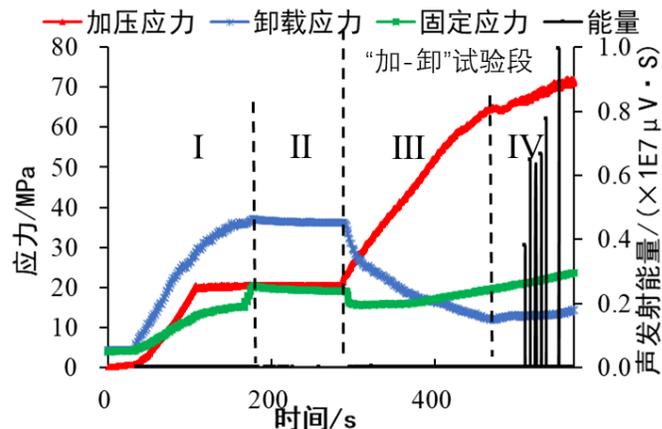
### “加-卸” 应力路径转换



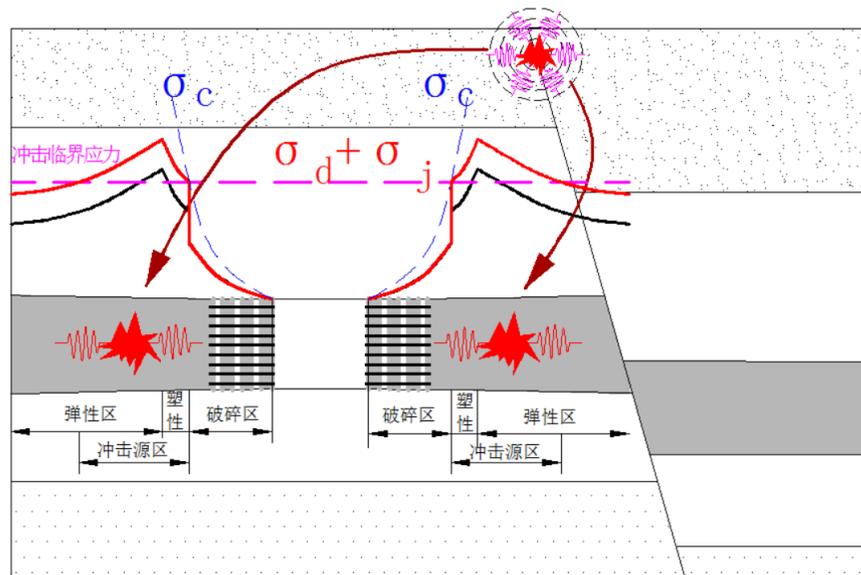
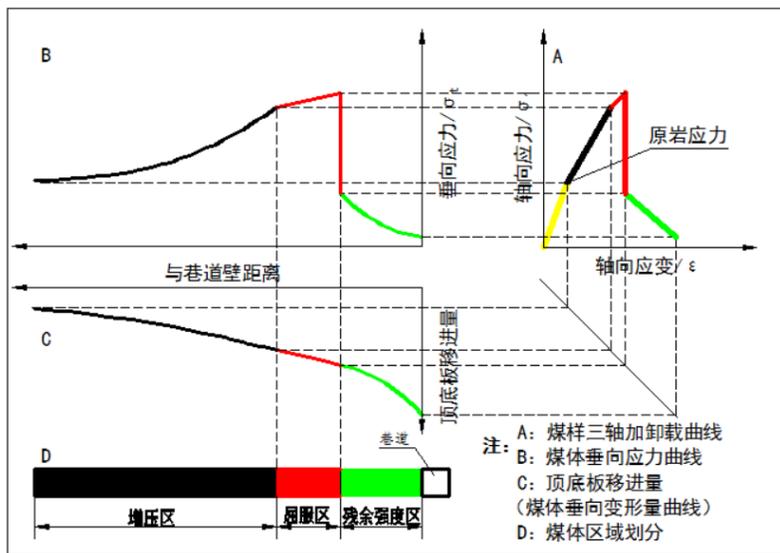
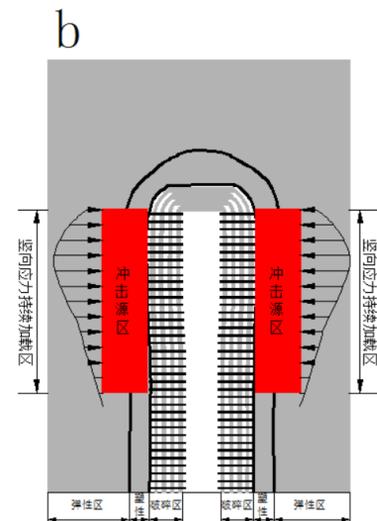
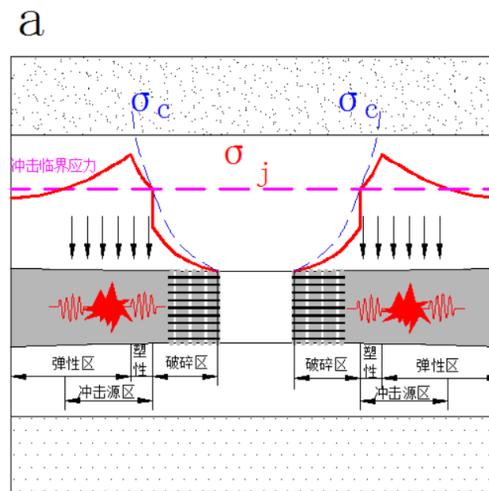
- 切向加载
- 径向卸载
- 走向应变不变”



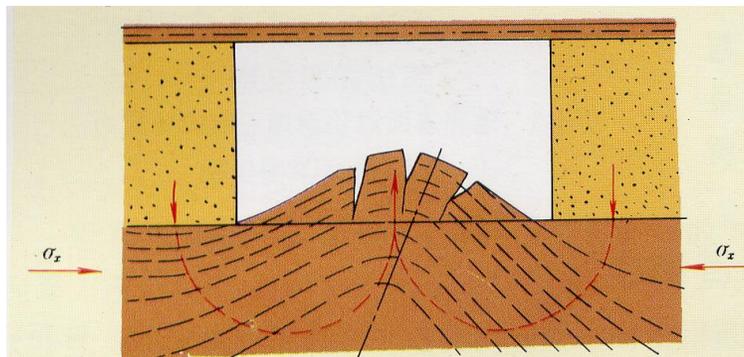
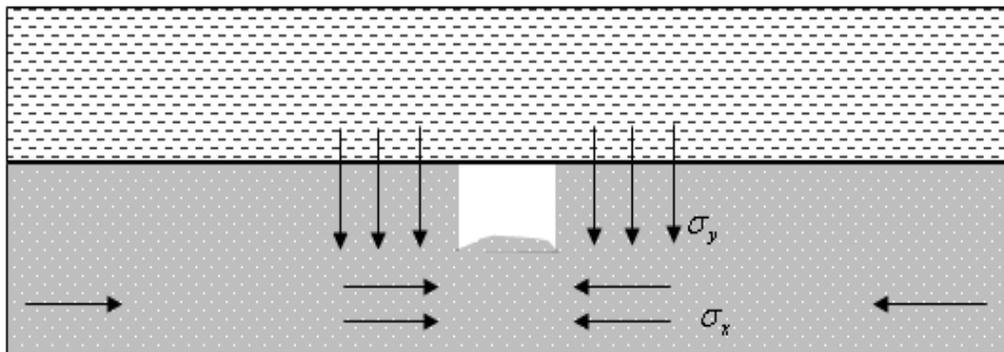
高加载侧应力



高卸载侧应力



## ➤ 巷道底板冲击判别模型



### 底板冲击矿压危险性系数

$$K_{fb} = k_1 k_2 \lambda K H \gamma_r \frac{B^2}{E h^2}$$

$$\sigma_x = k_2 \frac{\mu}{1 - \mu} \sigma_y$$

当  $K_{fb} \geq 1$  时，巷道底板岩层发生破坏。

- 底板冲击矿压危险性系数与巷道埋深，水平构造应力，巷道宽度的平方，巨厚坚硬老顶影响系数成正比；
- 与弹模、巷道底板软弱层厚度的平方成反比。

$\lambda$ 侧压系数；K，系数，取1.60~1.72； $k_1$ ，为坚硬老顶支承压力影响系数，为1； $k_2$ ，水平构造应力影响系数：