UNDERGROUND METALLIFEROUS MINING

Development

Presented by

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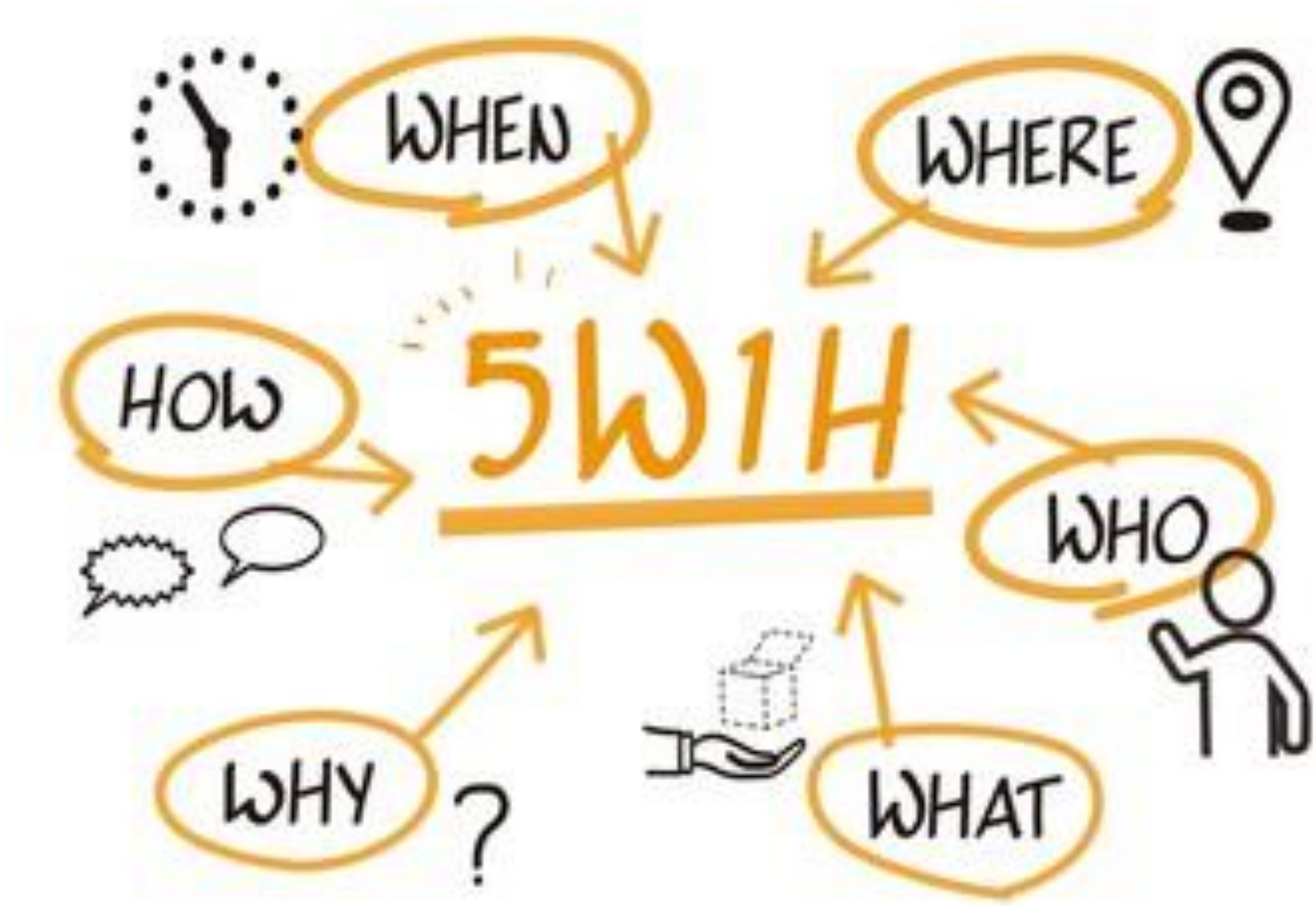
Content

- **Development**
  - Opening of deposits
    - Shafts (vertical and inclined)
    - Declines and adits
  - Cross-cuts
  - Division of orebody into levels and blocks
  - Level interval
  - Driving of raises
  - Conventional and raise boring machines methods

Development

- The work of **opening a mineral deposit** for exploitation.
- **Steps involved** :
  - Planning
  - Designing
  - Construction
  - Other phases.
- **Purpose :** To **provide access** to the ore deposit, permitting entry of the miners, egress for the mineral being mined and waste produced. Others include **preparatory work**, facilities, personnel, and services that support the mining.
- In underground mines, small sized openings are driven from the surface to intersect the orebody and eventually to **connect with large exploitation openings**.

Development



5WH of Mine Development

- **Who:** Mining engineers, geologists, environmental specialists, project managers, local communities, investors, and regulators.
- **What**: Development of ore bodies, mining infrastructure, processing facilities, and environmental management systems.
- **When**: Exploration, feasibility, construction, operational mining, and post-closure, spanning several years or decades.
- **Where**: The location of the ore body and associated infrastructure, often in remote areas requiring careful planning for access and environmental protection.
- **Why**: To extract valuable metals, support economic development, meet global demand, and generate profits.
- **How**: Through exploration, planning, permitting, construction, mining, processing, environmental management, and eventual decommissioning.

Factors in Mine Development

- **Location**
  - Ease of transport of materials
  - Availability of labor and support services
  - Operational impacts of climate and weather
- **Natural and Geologic Factors**
  - Topography and Terrain
  - Spatial relation of Ore Body
  - Geologic consideration (mineralogy, petrography, structure, ore body genesis, rock temperature gradient, presence of water, etc.)
  - Rock mechanics properties (strength, deformation, hardness, abrasiveness, etc.)
  - Chemical and metallurgical properties (effect on storage, processing, smelting, etc.)

Factors in Mine Development

- **Social-Economic-Political-Environmental Factors**
  - Demographic and occupational skills of local population.
  - Means of financing and marketing.
  - Political stability of host country.
  - Pollution legislation (air, water, waste, etc.).
  - Other governmental aids and restrictions.

Sequence of Mine Development

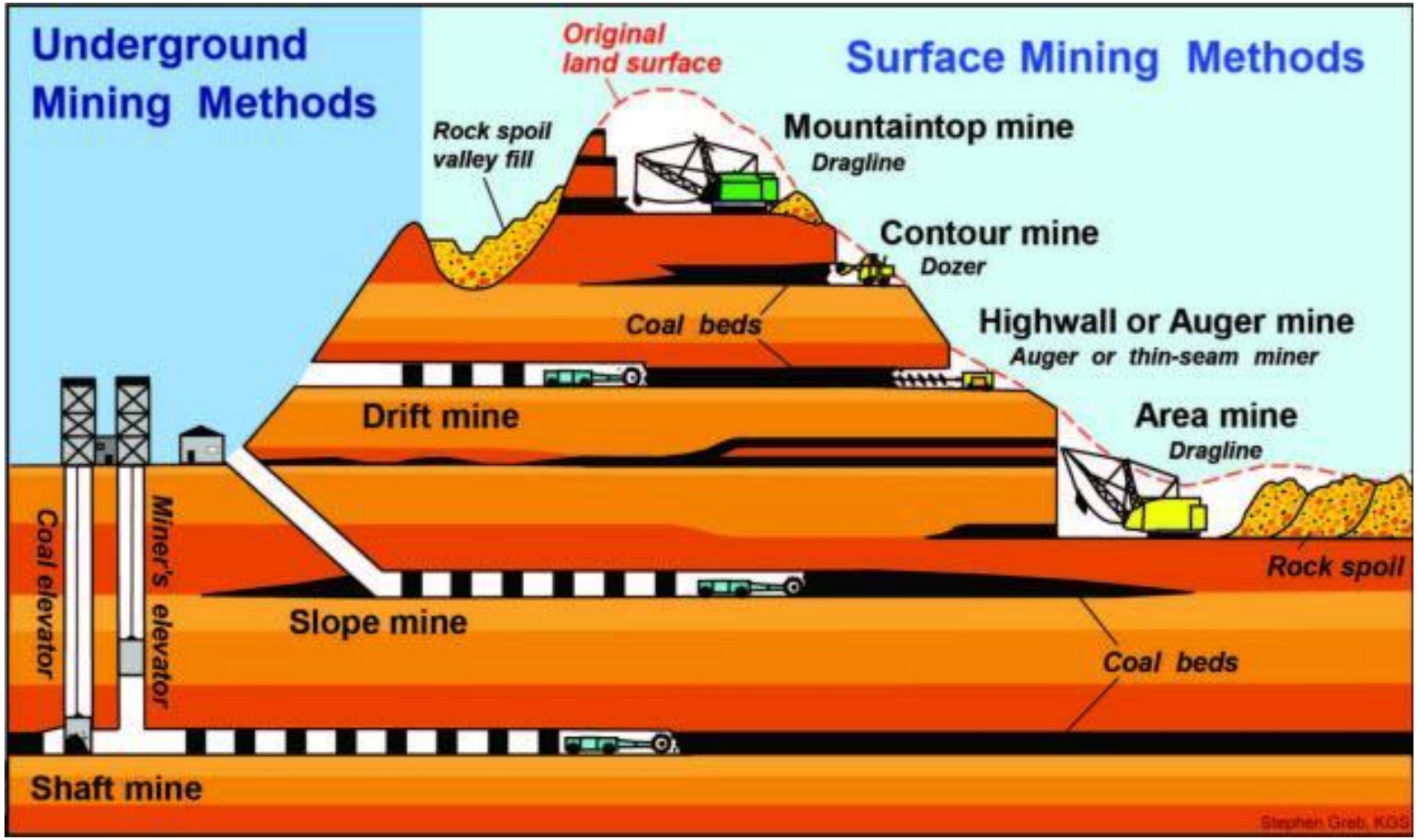
- **Adoption of a feasibility report** as a planning document (modifiable as development progresses).
- **Confirmation of mining method and general mining plan**
- **Arrangement of financing**, based on confirmed cost estimates from the feasibility report
- **Acquisition of land**, including mineral rights and surface, as needed
- **Filing of environmental impact statement**, obtaining of mining permits (including reclamation plan, if a surface mine), and posting of bonds subject to both federal and state statutes, as applicable
- **Provision of surface access, transportation, communication, and power supply** to the mine site
- **Planning and constructing of surface plant**, including all support and service facilities and administrative offices

Sequence of Mine Development

- **Erection of mineral processing plant**, if required, and ore-handling and shipment facilities, and provision of stockpiling and waste disposal facilities
- **Selection of mining equipment** for development and exploitation, with acquisition as needed
- **Construction of main access openings** to ore body and such secondary openings as required—including, in surface mining, advanced stripping, and, in underground mining, shafts and certain other subsurface facilities
- **Recruitment and training of labor force** and provision of support services (housing, transportation, consumer stores, etc.), as necessary, with attention to other social-political-economic needs of employees

Underground Development Openings – Types and Order

- **Primary**
  - Main openings
  - E.g., shaft
- **Secondary**
  - Level or zone opening
  - E.g., Drift, Entry
- **Tertiary**
  - Lateral or Block openings
  - E.g. Ramp, Crosscut



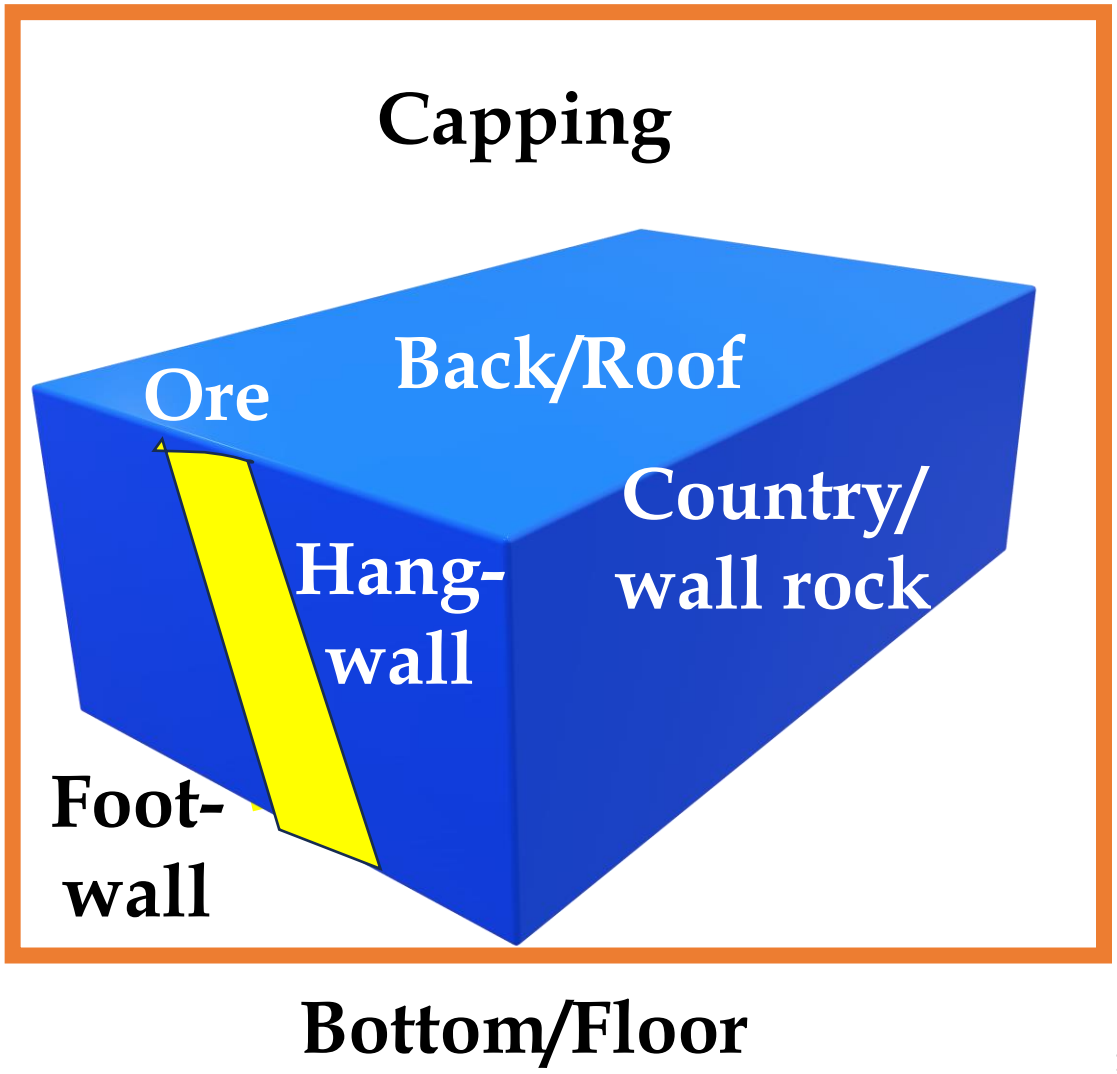
- To **connect surface with exploitation** openings located underground.

Source: https://www.worldcoal.org/coal/coal-mining/

Terminology

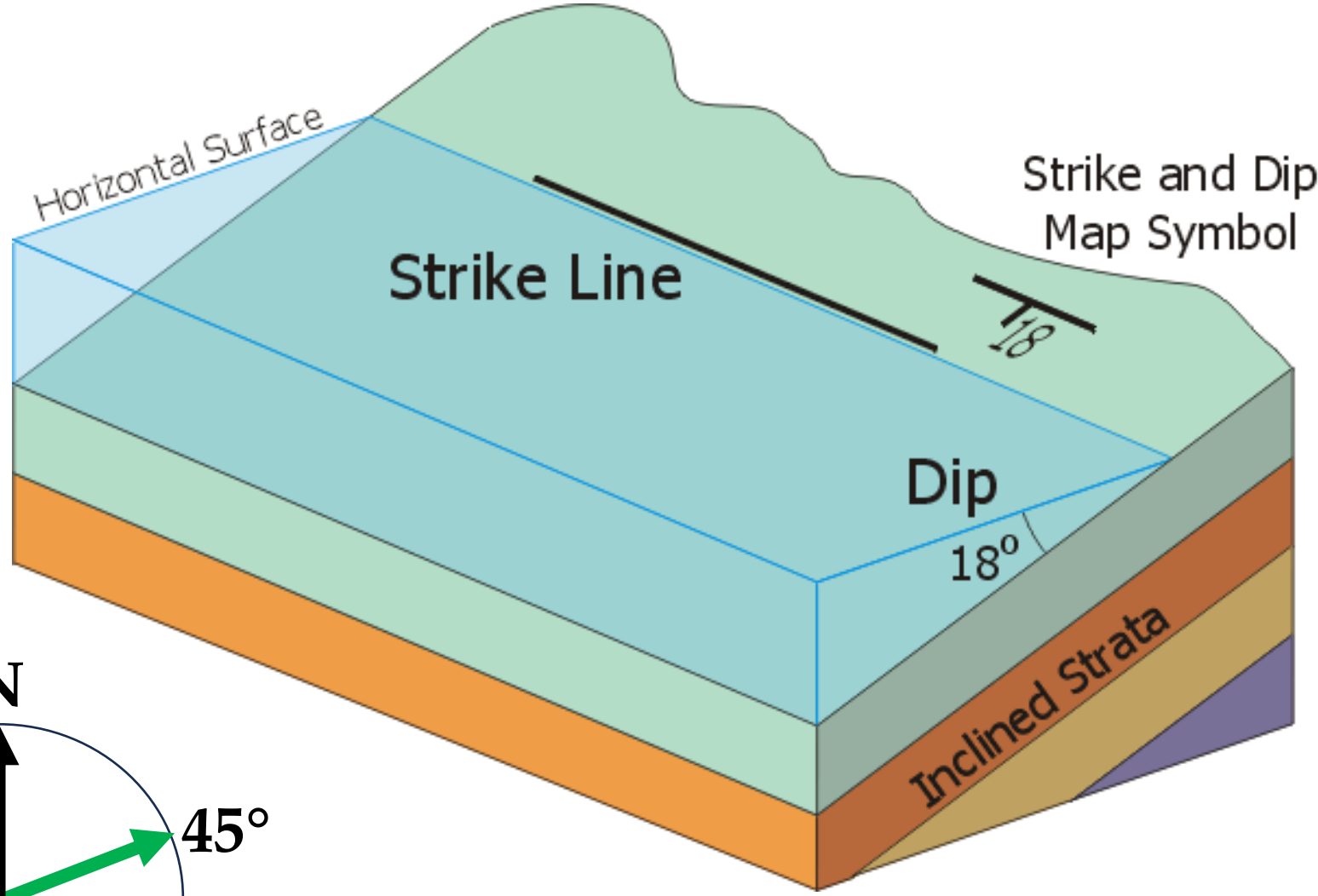
Deposit and Spatial Terms

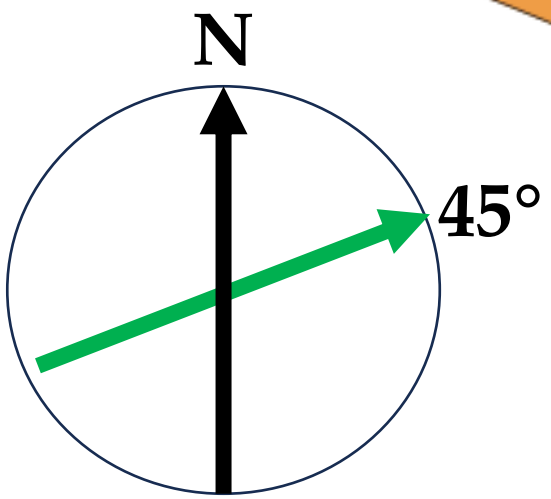
- **Back or Roof**: Roof, top, or overlying surface of an underground excavation
- **Bottom or Floor**: Floor or underlying surface of an underground excavation
- **Capping**: Waste material overlying the mineral deposit
- **Country/wall rock**: Waste material adjacent to a mineral deposit
- **Footwall**: Wall rock under the deposit
- **Hanging wall**: Wall rock above a deposit



Deposit and Spatial Terms

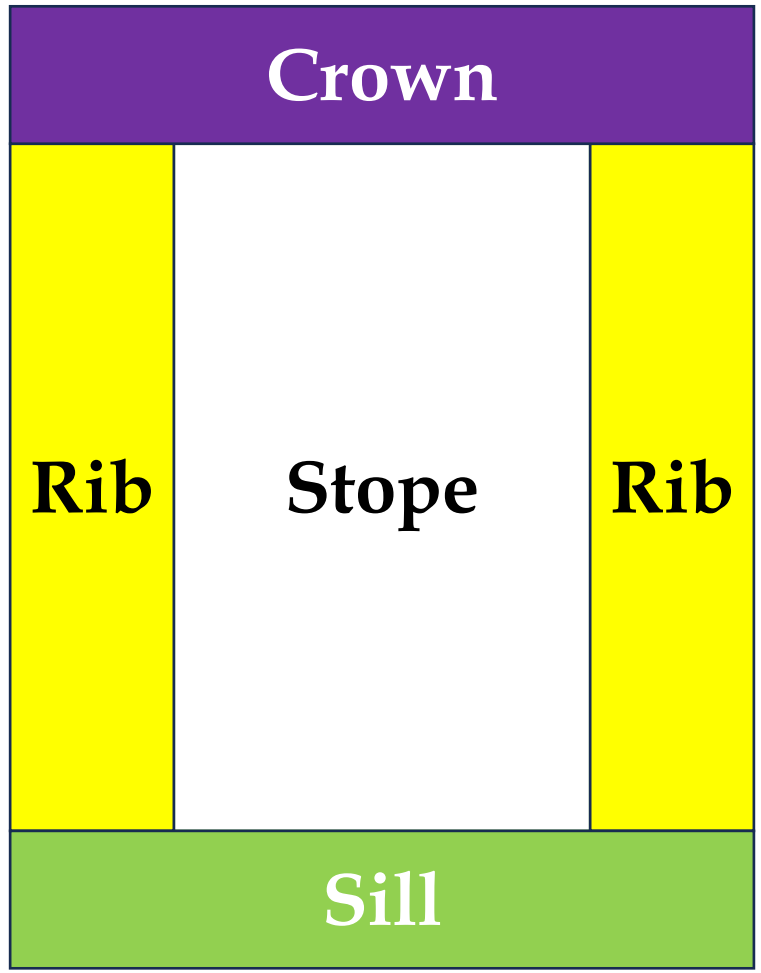
- **Strike**: Horizontal bearing of a tabular deposit at its surface intersection
- **Dip**: Angle of inclination of a deposit, measured from the horizontal; also pitch or attitude





Deposit and Spatial Terms

- **Stope**: Broken, caved, and mined-out portion of the deposit
- **Pillar**: Unmined portion of the deposit, providing support to the roof or hanging wall
- **Crown pillar**: Portion of the deposit overlying an excavation and left in place as a pillar
- **Sill pillar**: Portion of the deposit underlying an excavation and left in place as a pillar
- **Rib**: Side wall of an excavation; also rib pillar



Directional Terms

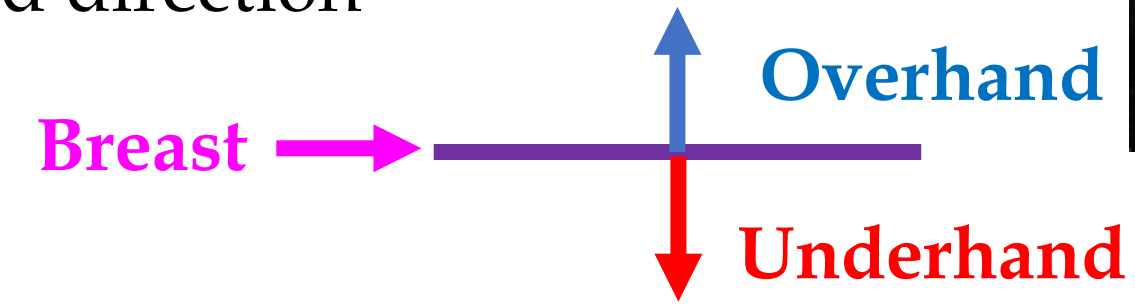
- **Inby**: Toward the working face, away from the mine entrance
- **Outby**: Away from the working face, toward the entrance
- **Breast**: Advancing in a near-horizontal direction; also, the working face of an opening
- **Overhand**: Advancing in an upward direction
- **Underhand**: Advancing in a downward direction

Outby

Inby

Mine Entrance

Working Face



Excavation Terms

- **Adit**: Main horizontal or near-horizontal underground opening, with **single access** to the surface
- **Tunnel**: Main horizontal or near-horizontal opening, with access to the surface at **both ends**.
- **Decline**: Secondary inclined opening, driven **downward** to connect levels, sometimes on the dip of a deposit; also declined shaft
- **Incline**: Secondary inclined opening, driven **upward** to connect levels, sometimes on the dip of a deposit; also inclined shaft
- **Drift**: Primary or secondary horizontal or near-horizontal opening; oriented parallel to the strike of a pitching deposit
- **Entry**: Secondary horizontal or near-horizontal opening; usually driven in multiples
- **Portal**: Opening or connection to the surface from an underground excavation.

Excavation Terms

- **Crosscut**: Tertiary horizontal opening, often connecting drifts, entries, or rooms; oriented perpendicularly to the strike of a deposit; also breakthrough
- **Haulageway**: Horizontal opening used primarily for materials handling
- **Bell**: Funnel-shaped excavation formed at the top of a raise to move bulk material by gravity from a stope to a drawpoint
- **Bleeder**: Exhaust ventilation lateral
- **Chute**: Opening from a drawpoint, utilizing gravity flow to direct bulk material from a bell or orepass to load a conveyance
- **Drawpoint**: Loading point beneath a stope, utilizing gravity to move bulk material downward and into a conveyance, by a chute or loading machine; also boxhole
- **Finger raise**: Vertical or near-vertical opening used to transfer bulk material from a stope to a drawpoint; often an interconnected set of raises

Excavation Terms

- **Lateral**: Secondary or tertiary horizontal opening, often parallel or at an angle to a haulageway, usually to provide ventilation or some auxiliary service.
- **Level**: System of horizontal openings connected to a shaft; comprises an operating horizon of a mine.
- **Loading pocket**: Transfer point at a shaft where bulk material is loaded by bin, hopper, and chute into a skip.
- **Longwall**: Horizontal exploitation opening several hundred feet (meters) in length, usually in a tabular deposit.
- **Manway**: Compartment of a raise or a vertical or near-vertical opening intended for personnel travel between two levels.
- **Orepass**: Vertical or near-vertical opening through which bulk material flows by gravity.

Excavation Terms

- **Raise**: Secondary or tertiary, vertical or near-vertical opening, driven upward from one level to another.
- **Winze**: Secondary or tertiary vertical or near-vertical opening, driven downward from one level to another.
- **Ramp**: Secondary or tertiary inclined opening, driven to connect levels, usually in a downward direction, and used for haulage.
- **Room**: Horizontal exploitation opening, usually in a bedded deposit.
- **Shaft**: Primary vertical or near-vertical opening, connecting the surface with underground workings; also vertical shaft.
- **Slope**: Primary inclined opening, usually a shaft, connecting the surface with underground workings.
- **Slot**: Narrow vertical or inclined opening excavated in a deposit at the end of a stope to provide a bench face.

Excavation Terms

- **Stope**: Large exploitation opening, usually inclined or vertical, but may also be horizontal.
- **Sublevel**: Secondary or intermediate level between main levels or horizons, usually close to the exploitation area.
- **Transfer point**: Location in the materials-handling system, either haulage or hoisting, where bulk material is transferred between conveyances.
- **Undercut**: Low horizontal opening excavated under a portion of a deposit, usually a stope, to induce breakage and caving of the deposit; also a narrow kerf cut in the face of a mineral deposit to facilitate breakage.
- **Grizzly**: Coarse screening or scalping device that prevents oversized bulk material from entering a material transfer system; constructed of rails, bars, beams, etc.

Mine Development and Design

- **Mining Method**
  - Selection
  - Governs the placement of primary development openings.
  - Advance or retreat.

- **Production Rate and Mine Life**
  - Optimum rate of production from a mineral deposit of known reserve, hence life of mine.
  - Market conditions, selling price of products, mineral grade, development time, mining cost, means of financing, governmental support and taxation policies.
  - Optimise net present value (revenue – mining costs) – i.e., maximise internal rate of return

Main Access Openings

Primary development shall depend on:

- **Type of openings**
  - **Vertical or inclined shaft**

    Preferred for large, deep, or flat deposits, for intermediate to poor natural conditions, for high production rates, used along with with skip hoisting.
  - **Decline**

    For shallow, flat deposits, for belt conveyor and truck haulage,
  - **Drift (adit)**

    For outcrops, usually in high relief areas and shallow covers, or steeply dipping deposits. Slope must be 3-5 times longer to attain same depth as shaft.

Main Access Openings

- **Location of openings**
  - Should be in center of deposit.
  - Main opening is planned to intersect at the centroid to minimize haulage costs.
  - Considers, dip, ground condition, no. of working places, surface topography, transport, drainage, and property lines.
  - Choice of mining method also decides the location considering caving or subsidence possibilities.
- **Number of openings**
  - Depends on legal requirements for safety, ventilation, convenience of access to underground workings, production rate, spatial relations of the mineral deposits.
  - For safety - **at least two major openings** are required.
  - For ventilation – **two on extremities** to permit unidirectional flow of air, sometimes even raises and shafts are used.

Main Access Openings

- **Shape and Size of openings**

Function of type of opening, mode of construction, and means of materials handing employed.
Drilling & Blasting – rectangular openings
Shafts – circular or rectangular
Mechanical excavation – circular or elliptical
Round openings - Rock mechanics / ventilation perspective
Rectangular openings – for efficient space utilization, preferred for hoisting system as well
Size – function of material handling. Larger opening for higher production rates.

- **Design of materials-handling system**

Main Access Openings

- **Interval Between Levels**
  - Shall yield **lowest overall mining cost**.
  - Configuration of a mineral deposit or type of mining method shall take precedence in locating and spacing levels.
  - Depends on cost estimate.
  - **Development cost** (constructing, equipping, and supporting openings and installing material-handling facilities) increases with number of levels.
  - However, **exploitation costs** reduces with increasing number of levels.
  - **Calculate development, exploitation and overall mining cost for different intervals, plot them and select the interval corresponding to lowest overall costs**.
  - With mechanisation – fewer levels are preferred (30-90m and 90-240m).

Main Access Openings

- **Factors influencing** are:
  - Depth, shape and size of deposit
  - Surface topography
  - Natural and geologic conditions of ore and overlying waste
  - Mining method
  - Production rate

Secondary Development Layout

- **Secondary and Tertiary development openings** – usually constructed during exploitation.
- Planned during conceptual stage itself.
- Considerations for designing :
  - Materials handling of ore
  - Access for the miners & material
  - Circulation of ventilation air
- On the Level : minimum number of drifts and cross cuts for access, haulage, and ventilation, locating them in the footwall.
- Raises, winzes, ramps, and special purpose openings such as orepasses, ventilation raises, manways, etc. are located between levels.
- Should aid deepening of mine.

Mine Plan Layout

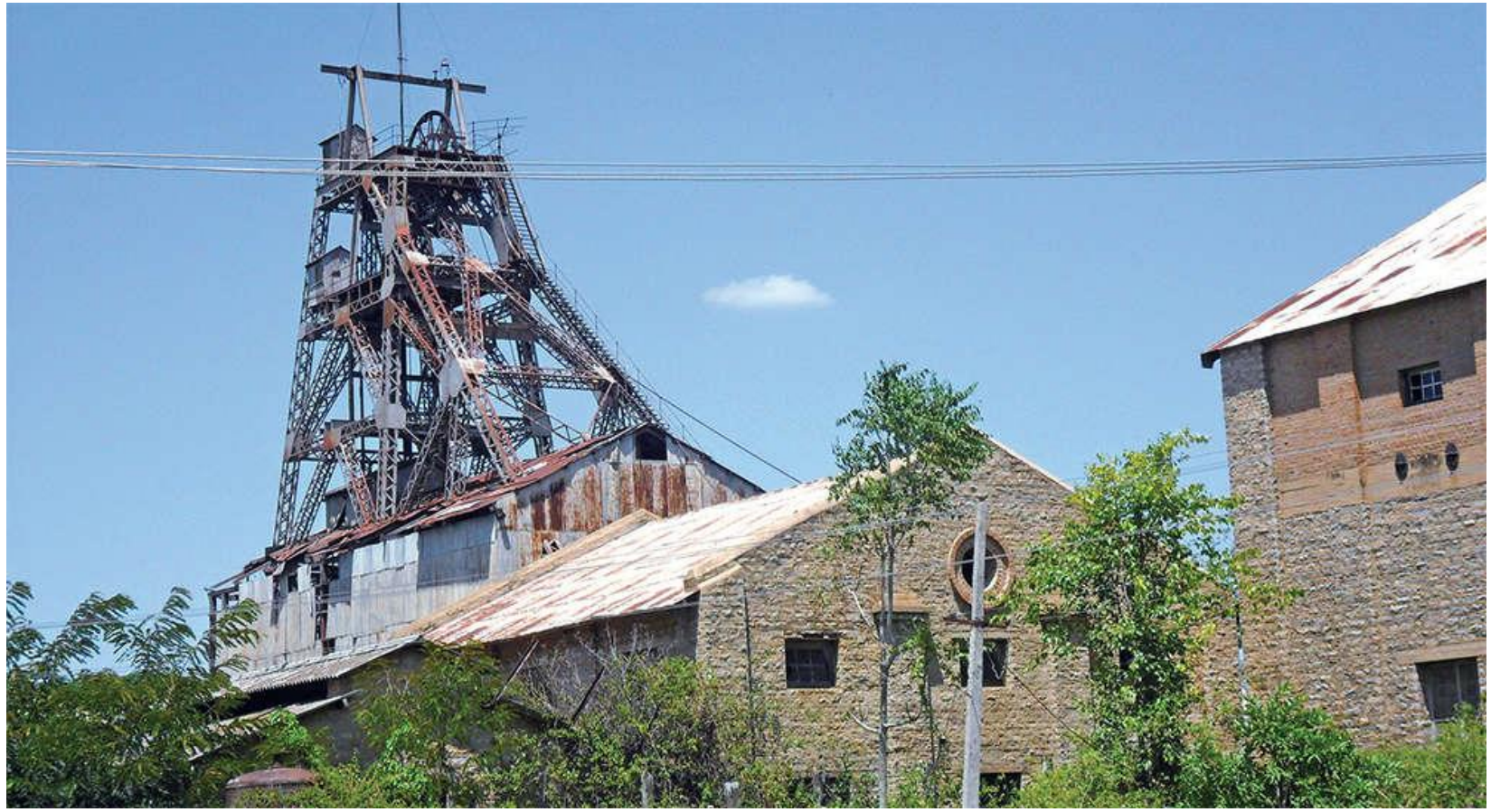
- Surface
- Shaft
- Underground

Mine Plan Layout - Surface

- Access roads, parking, transportation facilities, power supplies and utilities, service and maintenance buildings, administration and personnel buildings, mineral processing plant, bulk storage, and waste-disposal facilities for air water and solids, facilites for shaft, decline, adit, storage bins, etc.

Mine Plan Layout - Shaft

- Main access opening.
- Facilities include material handling, and means of transport of miners and material, hoisting systems, arrangement for ventilation, drainage, power supply, and communication.



Mine Plan Layout - Shaft

- **Two access openings are required**.
  - **Vertical Shaft with hoisting** – For deep horizontal (<30°), vertical to steeply inclined (>70°), bad natural conditions, high production, long life.
  - **Inclined Shaft with hoisting** – For moderately inclined (30-70°) deposits, moderate conditions, low-moderate production and life, shortens horizontal development and allows exploration during sinking.
  - **Slope or Decline with haulage** – For shallow, horizontal deposits, good to moderate conditions, moderate to high production, long life, can install rope hoisting, use with rail haulage, limited to 12° with trucks and 20° with conveyor.
  - **Drift or adit with haulage** – for shallow outcrop, horizontal deposit or steeply inclined deposit in area of high relief, varied conditions, high production, long life.

Shafts

- **Shafts** are vertical or near-vertical tunnels constructed to provide access to an underground mine.
- They are one of the most common methods of reaching ore bodies that are deep below the surface.

Shafts

- **Vertical Shafts:** These shafts are the most common for deep underground mines. They are constructed vertically from the surface down to the ore body, sometimes going several kilometers deep. Vertical shafts are used for the transport of workers, equipment, and materials, and for ventilation purposes.
- **Inclined Shafts:** Inclined shafts are at an angle to the horizontal, usually sloping at angles of **15 to 45 degrees**. They are typically used when the ore body is situated at a steep angle or in situations where constructing a vertical shaft might be too costly or impractical. They also provide better access for some types of mining methods, such as those in steeply dipping ore bodies.

Shafts

Advantages of Shafts:

- Efficient access to deep ore bodies.
- Can support heavy transport systems like hoists for ore extraction.
- Allows for the installation of ventilation systems for underground mines.

Disadvantages:

- Expensive to construct, especially if very deep.
- Requires significant engineering to ensure structural integrity and safety.

Decline

- A decline is an inclined tunnel that typically slopes downwards at a relatively low angle, usually around 10 to 20 degrees, depending on the geological conditions and mining requirements. Declines are generally used for shallower deposits but are also employed in some intermediate-depth operations.
- Construction and Use: A decline is typically constructed using drilling and blasting techniques, although in some cases, tunnel boring machines (TBMs) may be employed. Declines are often used in hard rock mining to access ore bodies at lower depths, and they are more cost-effective for shallower deposits compared to vertical shafts.
- Primary Functions:
  - Accessing ore bodies at shallow to intermediate depths.
  - Transporting miners, equipment, and materials.
  - Ventilation routes for the mine.

Decline

- Advantages of Declines:More cost-effective than vertical shafts for shallow to intermediate deposits.Easier construction in some geological settings (such as soft rock).Can be used for dual purposes: providing access and transporting materials.
- Disadvantages:Limited to deposits where the ore body is located at a relatively shallow depth.Can be inefficient in transporting large volumes of ore from very deep deposits.

Adit

- An adit is a horizontal or nearly horizontal tunnel driven into the side of a hill or mountain to access an ore body. Adits are typically used for shallow ore bodies located at or near the surface.
- Construction and Use: Adits are typically driven from a hillside or the side of a mountain, providing a direct route into the ore body. They are often used for initial exploration or development of shallow mines. The primary function of an adit is to provide access to ore bodies and serve as a means for ventilation and escape.
- Primary Functions:Accessing near-surface ore bodies.Ventilation.Drainage of groundwater.Transport of materials, ores, and waste rock.

Adit

- Advantages of Adits:
- Cost-effective for shallow ore bodies.
- Can be used for direct extraction of ore close to the surface.
- Natural ventilation is often better than in deeper mines.
- Disadvantages:
- Only suitable for shallow ore bodies (i.e., those exposed or close to the surface).Limited depth of penetration.

Cross Cut

- In metal mining, a cross-cut is an important underground excavation used to access and explore ore bodies or to establish mining routes that connect different parts of the mine. These horizontal or slightly inclined tunnels (also referred to as "drifts" in some cases) are driven perpendicular to the strike of the ore body and are essential for efficient mining and ore extraction.

Cross Cut

- A cross-cut is typically used in underground mining operations to connect various tunnels or workings within the mine. These passages serve as essential routes for the following:
- Accessing Ore Bodies: Cross-cuts can be driven from a main drift or tunnel to reach an ore body. By cutting through the rock in a horizontal or slightly inclined direction, a cross-cut intersects the vein or ore body, providing access to it.
- Ventilation: Cross-cuts can help provide airflow throughout the mine. By connecting different parts of the mine, they allow air to circulate from one working area to another, improving ventilation in deeper and more remote sections of the mine.
- Transport: Cross-cuts are used to establish transportation routes for ore, waste, and materials. They allow the flow of miners, machinery, and supplies between different parts of the underground workings.

Cross Cut

- Exploration: In the early stages of mining, cross-cuts are often used for exploration purposes. By cutting across the ore body, geologists and mine planners can gather information about the size, grade, and orientation of the deposit.
- Safety: In addition to their other functions, cross-cuts are also used to provide secondary escape routes in case of emergency, improving the overall safety of the mine.

Comparison between Shaft, Decline and Adit

Method	Depth Range	Construction Cost	Transport Efficiency	Common Use Case
Shaft (Vertical)	Deep (>1000 m)	High	Very efficient	Deep, vertical ore bodies
Shaft (Inclined)	Moderate to deep	High to moderate	Efficient	Steeply inclined ore bodies, deep deposits
Decline	Shallow to moderate	Moderate	Moderately efficient	Access for shallow to intermediate ore bodies
Adit	Shallow (<200-300 m)	Low	Less efficient	Surface or near-surface ore bodies

Mine Plan Layout - Underground

- **Secondary and Tertiary mine openings**
- **Specialized openings** – horizontal openings intersecting the vertical ones, transition from haulage to hoisting at shaft station.

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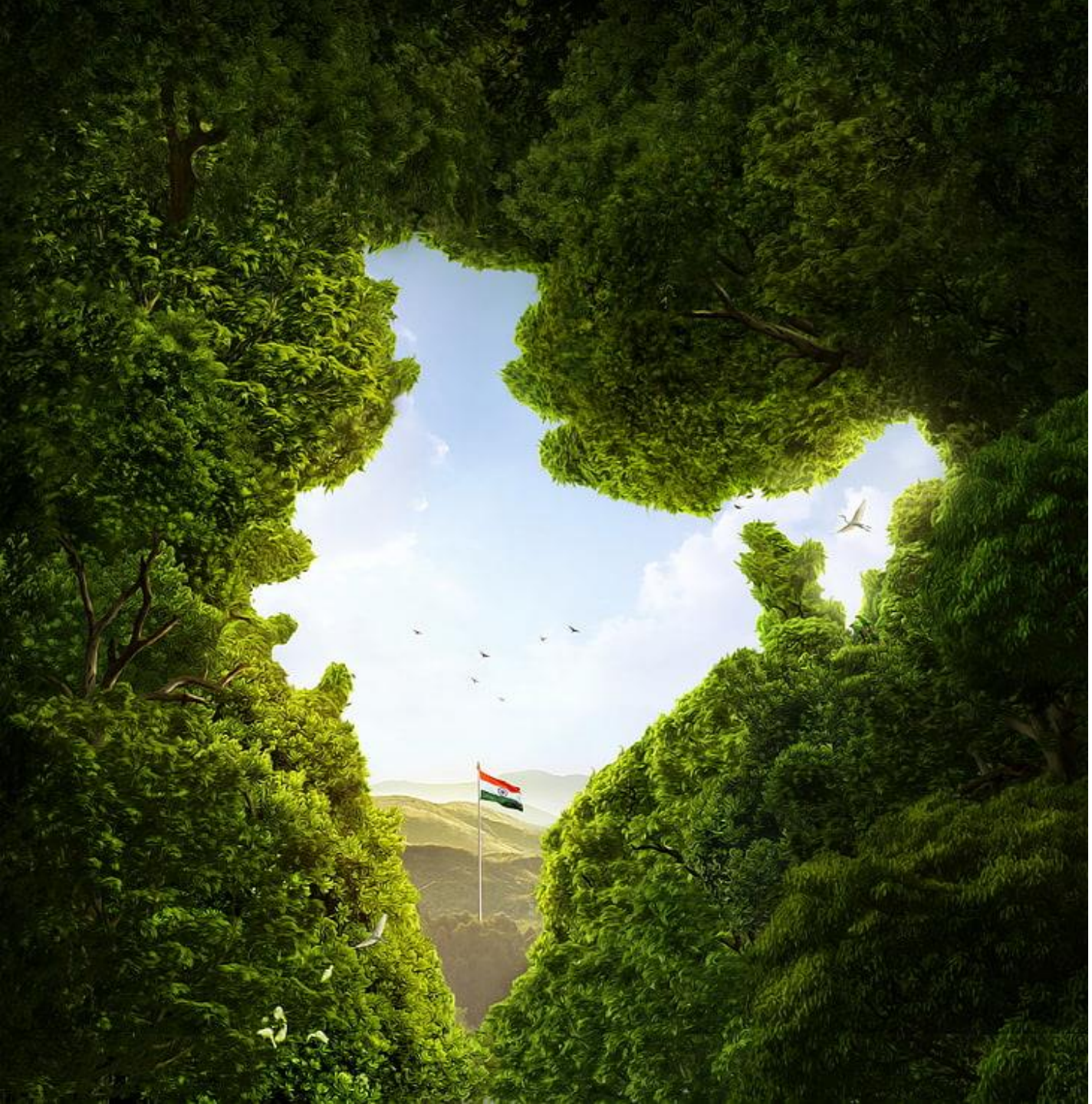

Thank You

Any Queries ???

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