Carnegie Mellon

NETL

Design of High Performance Drilling Fluids: Challenges And Future Directions for HP/HT Fluids

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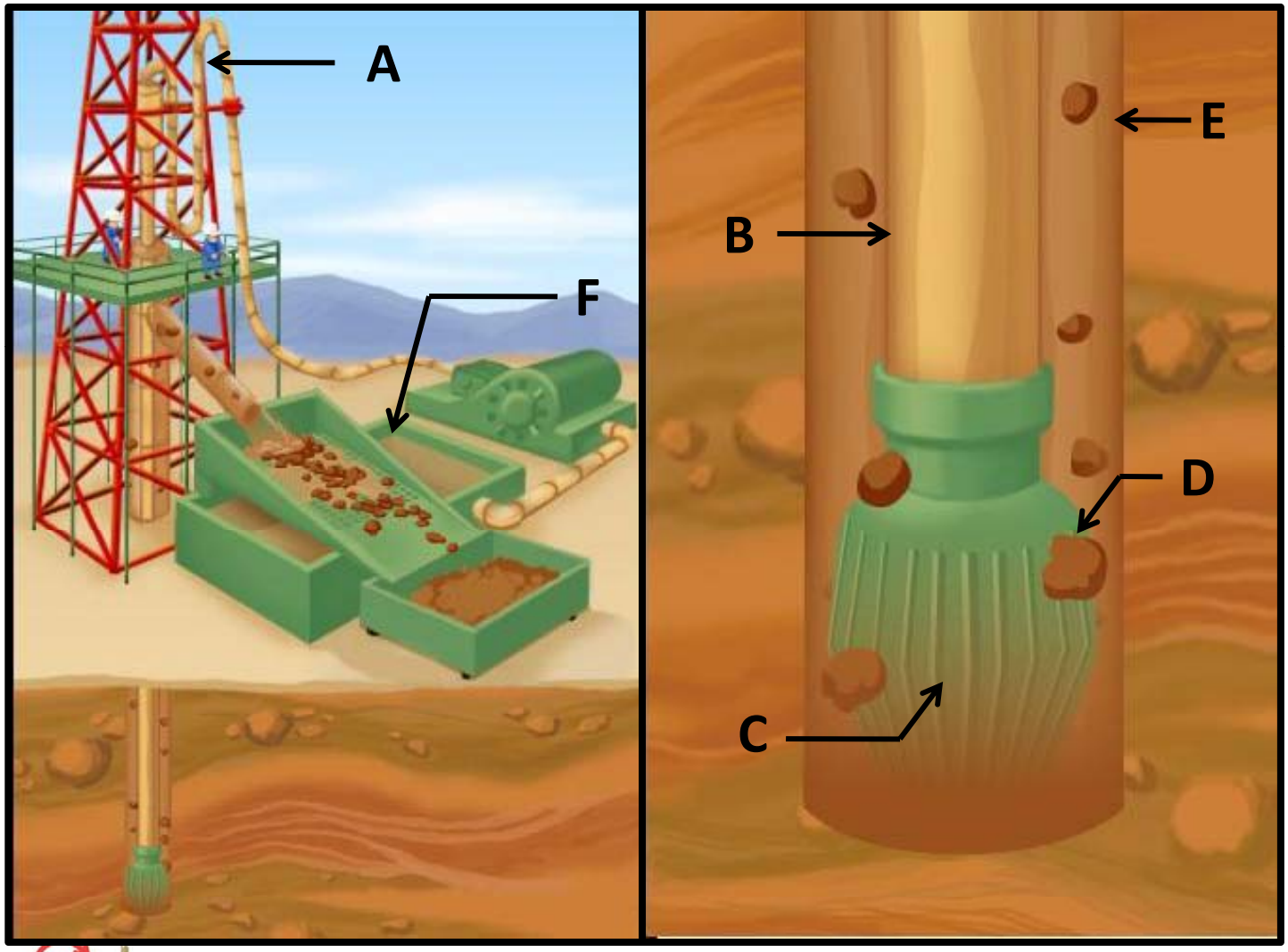
Chemical ENGINEERING

CAPD CENTER

Deep Drilling

- World energy demand continuously increasing
- Total estimated conventional gas resources at depths > 4.5 km = 844 TCF
- No. of deep wells disproportionately small compared to their potential
  - Costs are an order of magnitude higher
  - High costs limit the number of deep wells
  - Drilling amounts to 50% of the total well costs
  - Last 10-20% of the bore hole can account for 50% of the total cost

Drilling Process



A Drill pipe

B Drill string

C Drill bit

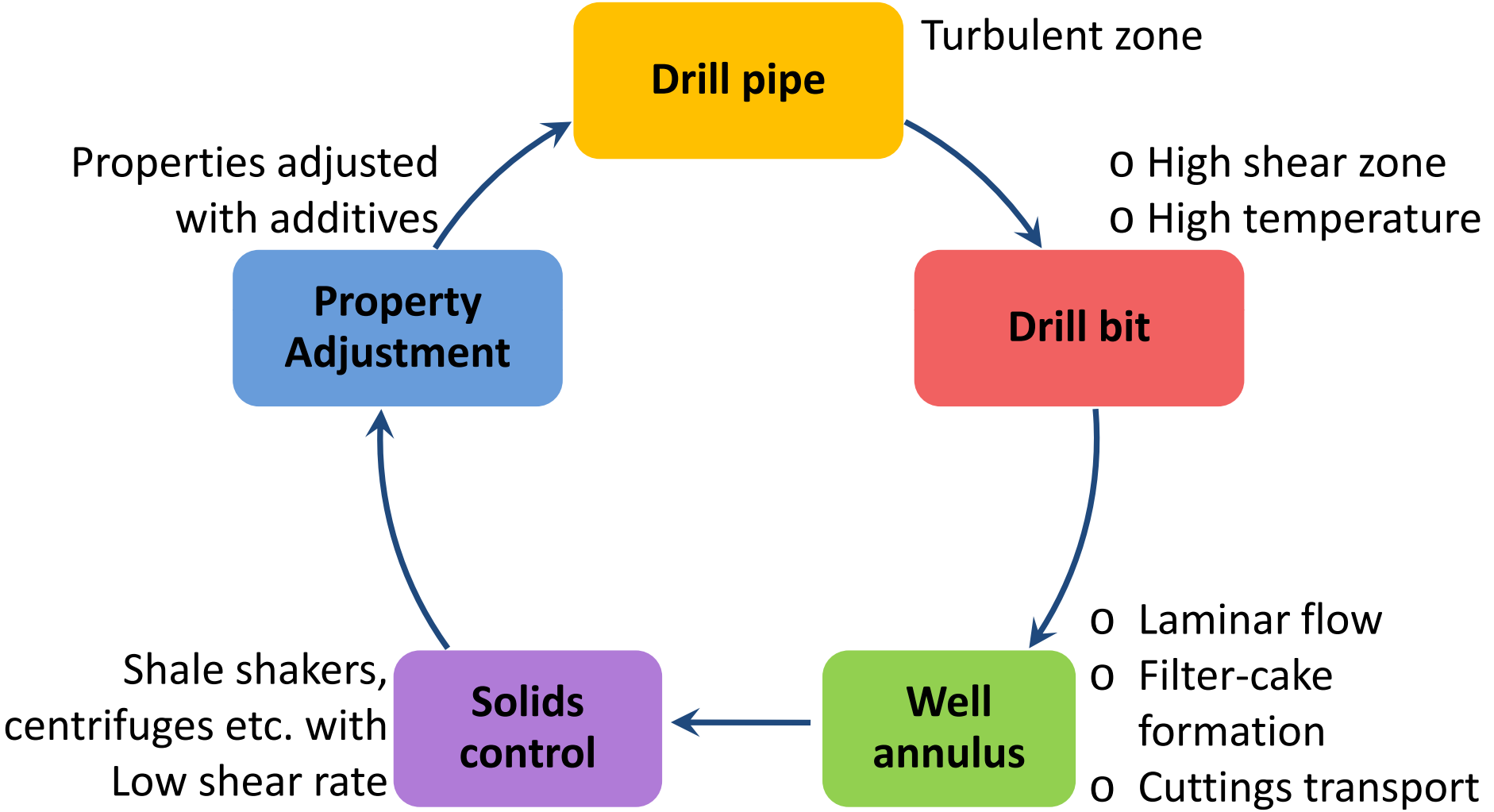
D Rock cuttings

E Annulus

F Solid separation devices

Source: Schlumberger Excellence in Educational Development (SEED)

Drilling Cycle



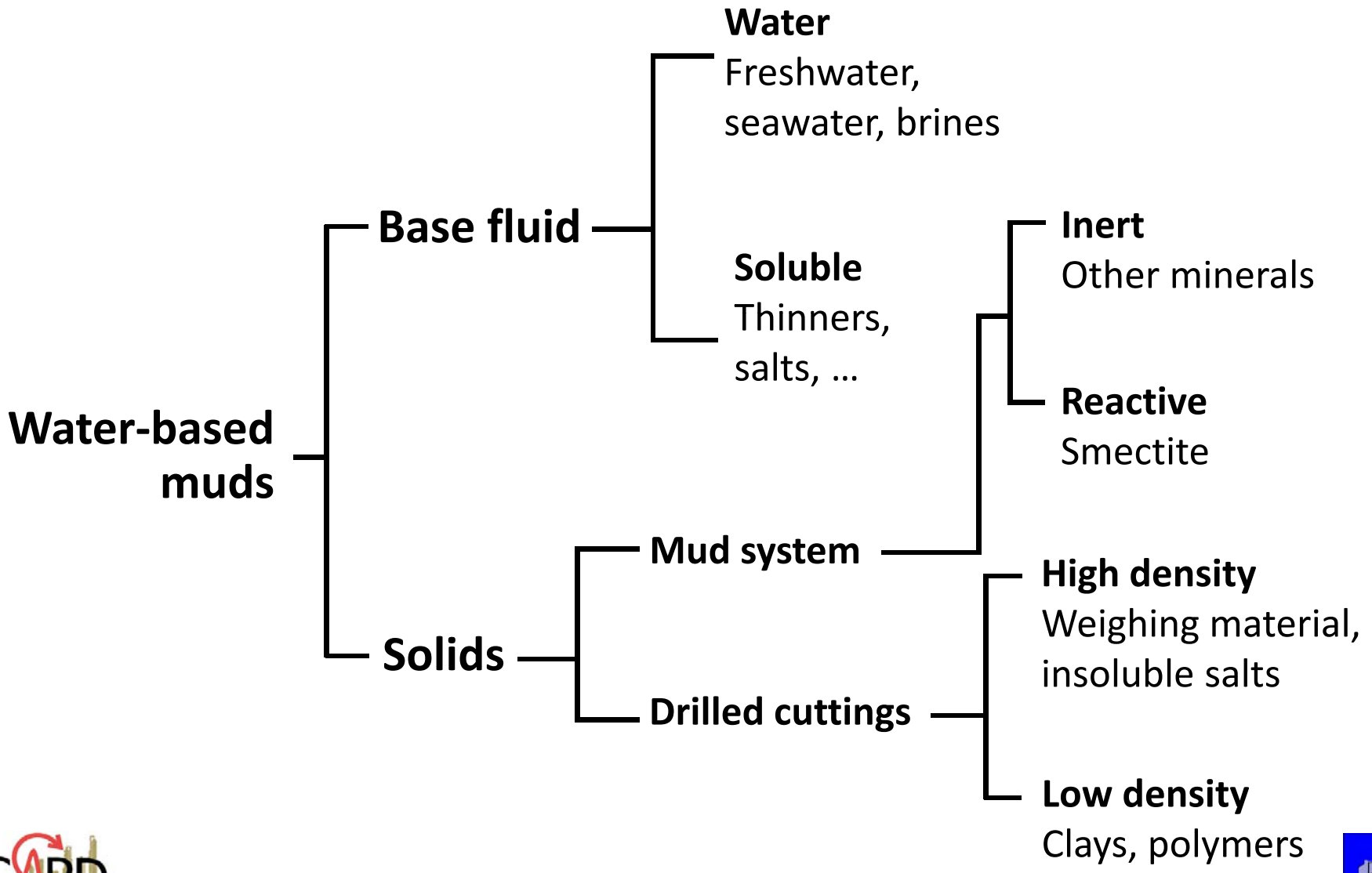
Functions of Drilling Fluids

- Remove and transport drilled cuttings
  - Removal increases rate of penetration
- Cool and lubricate the drill bit
  - Increase lifespan of the bit
- Seal the wall in permeable formations
  - Form a filter cake to reduce loss of circulation
- Control pressure in the drilled formation
  - Stability and efficiency affected greatly by pressure
  - Manage gas kicks, formation liquid invasion etc.

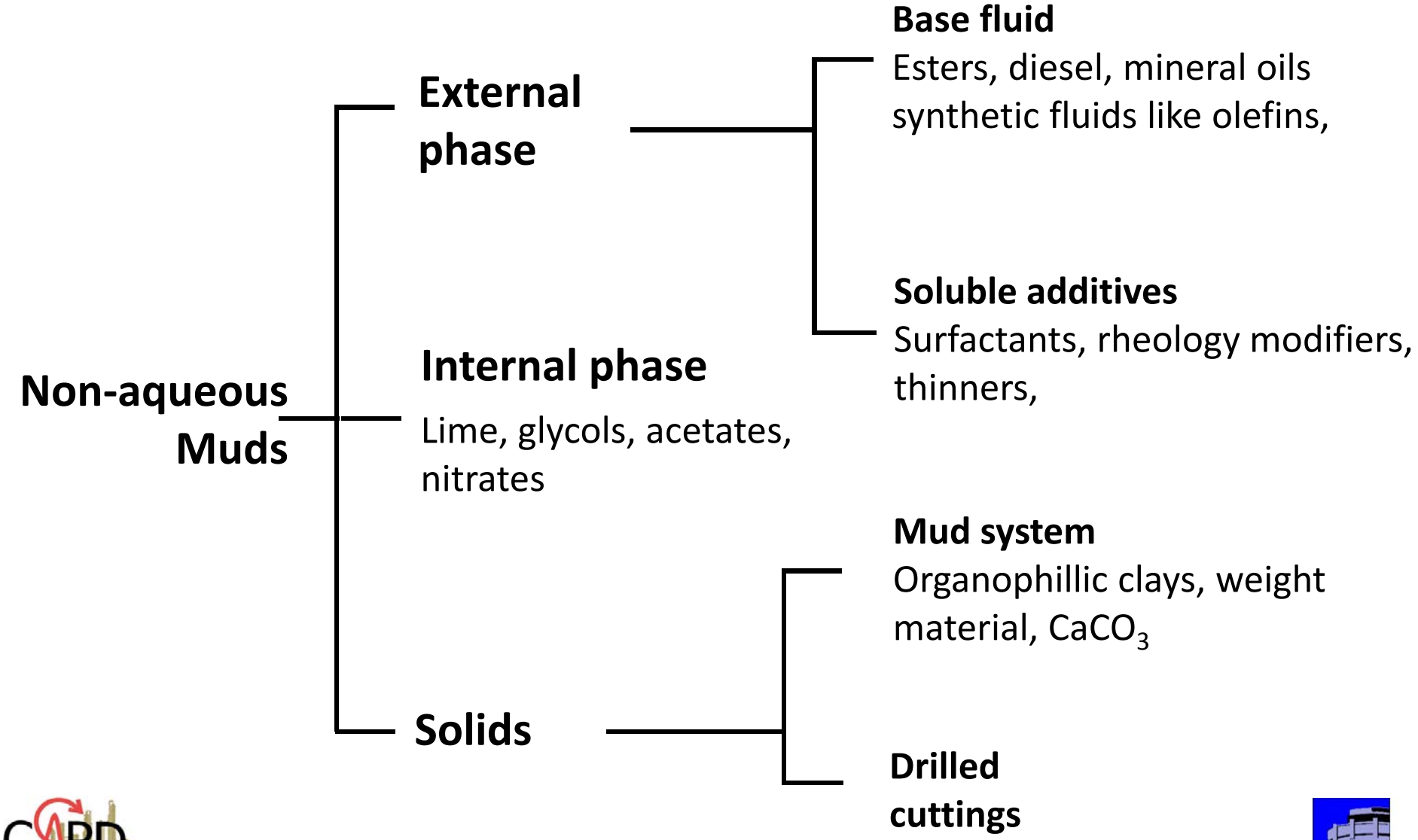
Functions of Drilling Fluids

- Minimize reservoir damage
- Permit formation evaluation
- Maintain well-bore stability
- Prevent corrosion and excessive wear
- Facilitate cementing and completion
- Inhibit gas hydrate formation
- Neutralize corrosive gases encountered

Components of Water-based Muds



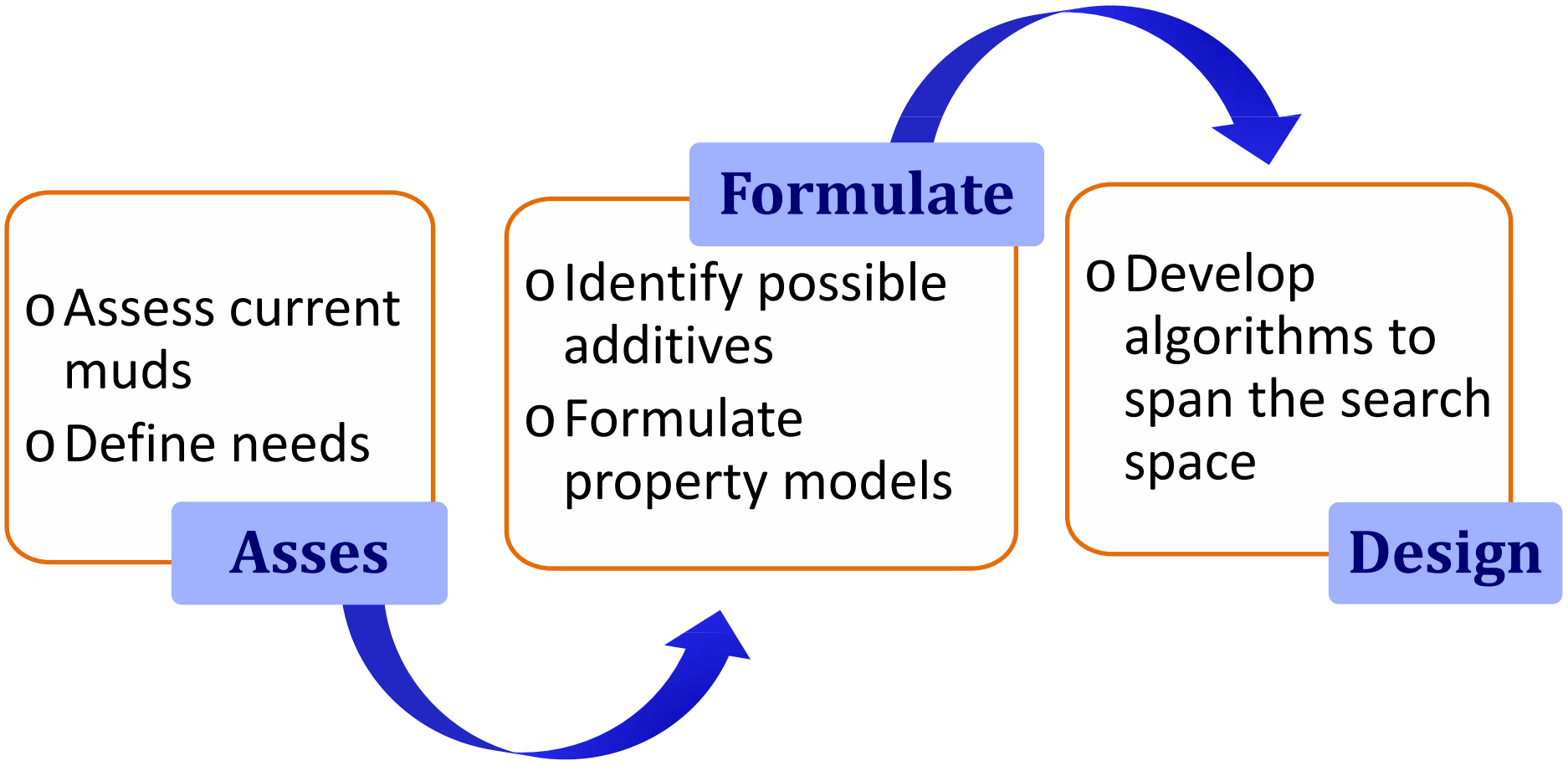
Components of Non-aqueous Muds



HP/HT Drilling Challenges

- Meet the demanding conditions
  - Depths > 20000 ft , Pressures up to 2000 bar, Temperatures up to 250°C
- At extreme conditions low ROP leads to high costs
  - Additive degrade
  - Mud breaks down
  - Mud behavior difficult to predict
- Performance vs. Environmental acceptance

Design Process



Assessment of Current Muds

- Asses conditions of failure for current drilling fluids and additives
  - Define the targets for Computer-Aided Molecular Design (CAMD)
- Identify classes of components used for drilling
- Over 500 patents in just last 10 years
- Review of drilling fluid additives tailored for extreme conditions

Future Directions

- CAMD is an effective technique used for product design
- Key directions
  - Polymer additive design
  - Synthetic base fluid design
  - Surfactant system design
  - Tailoring mixture properties for optimal drilling parameters

Temperature Effects

- Examine the current additives
  - Stability and applicability range
- Degradation needs to be considered
  - Rate of decomposition as function of temperature
- Model for stability of mixtures
  - Colloidal mixture property models
  - Effects of temperature on colloidal stability
- Develop and include stability models

Polymer Additives

Approaches to polymer design

- Group Contribution (GC)
  - Contributions for some polymer properties using monomer structure
- Quantity-Structure Property Relations (QSPR)
  - Diverse structural descriptors to predict properties
- Connectivity Indices (CI)
  - Topological indices as descriptors for backbone and pedant groups

Polymer Design Challenges

- GC, CI fail with increasing size and complexity
- Difficult to include effects of
  - Branching
  - Co-polymers
- Lack of quality data for different systems
- Uncertainty present in property prediction
- Polymer additives deteriorate at high temperature

Other Key Areas

- Base fluid design
  - Targets: Expected rheology and stability
  - Environmentally conscious design
- Colloidal mixture design
  - Composition selection based on mixture stability models
  - Optimal weighing material size distribution
- Surfactant systems
- Lost-circulation material