Subsurface Temperature and Pressure

I. Subsurface Temperature
   a. BHT – bottom hole rock temperature from well and drill stem testing
   b. Geothermal Gradient
      i. Range 1.8 to 5.5 ^{o}C / 100m
      ii. Average: 2.5 ^{o}C / 100 m (25 ^{o}C / 1 km)
   c. Heat Flow
      i. Heat Flux = Geothermal Gradient x Thermal Conductivity of Rock
         1. transfer of heat energy per unit area
         2. Units: watts m^{-2} = (^{o}C m^{-1})(W m^{-1} $^{o}C^{-1}$)
         3. Watt = power = energy transfer per unit time
            a. 1 watt = 1 joule/sec = 1 N-m/sec

      ii. Rock Thermal Conductivity: function of porosity and depth of burial

Lithology	**Thermal Conductivity (W/m ^{o}C)**	
Halite	5.5	
Limestone	2.8-3.5	
Sandstone	2.6-4.0	Moral of Story: rock is a good insulator in general
Shale	1.5-2.9	
Coal	0.3	
Steel Bar Comparison	~50	
Aluminum	~150	

      iii. Bottom Hole Temperature Range
         1. Gulf Coast U.S. 15,000 – 20,000 ft depth ~350 F = 175 C
         2. Rio Grande Rift 15,000 – 20,000 ft depth ~375 F = ~180 C
         3. Deccan Rift India 15,000 ft depth, max temp ~390 F = ~190 C

II. Subsurface Pressure
   a. Pressure = force per unit area
      i. Force = push or pull action
         1. Measured in newtons
      ii. Pressure = force / area = N/m^2 = Pascal (Pa)
         1. Subsurface Pressure = weight / area = mass x g / area
   b. Overburden Pressure = total weight exerted per unit area of subsurface by rock material and fluids
      i. Lithostatic pressure = weight of rock material per unit area, transmitted through grain-grain contacts into subsurface
      ii. Fluid Pressure or "Pore Pressure"
         1. Hydrostatic Pressure = weight of fluids in pore space
         2. Hydrodynamic Pressure = fluid pressure related to potentiometric surface

Total Overburden Pressure = Lithostatic Pressure + Fluid Pressure

a. Lithostatic and fluid pressure are inversely proportional
b. Fluid Pressure >, Lithostatic Pressure <; and vice versa
   i. > Fluid Pressure analogous to "hydraulic lifting" of subsurface materials, with net decrease in downward directed weight

iii. Example Pressure Gradients
   1. Lithostatic Pressure Gradients– variable depending upon fluid pressure, common 1 psi/ft of depth
   2. Hydrostatic Pressure Gradients (temperature dependent; based on weight density)
      a. Water: 0.465 psi/ft
      b. Oil: 0.35 psi/ft
      c. Gas: 0.1 psi/ft

In-class Problems:

1. Assuming a lithostatic pressure gradient with depth of 1 psi/ft; determine the total lithostatic pressure in psi and kPa at the base of an 8000 ft section of sedimentary rock. Show all of your math work and unit algebra.

2. Assuming a fresh water pressure gradient of 0.465 psi/ft; determine the total hydrostatic pressure in psi and kPa for a lake that is 500 m deep. Show all of your math work and unit algebra.

---

3. Hydrodynamic Pressure – fluid potential gradient that drives flow to the well; defined by the elevation of the potentiometric or piezometric level to which fluids will rise in a well above it's base

Elevation of Potentiometric Level = (P/W) – (D – E)

Where P = bottom hole pressure (psi) W = unit weight of fluid (psi/ft) D = Depth (ft)
E = surface elevation of well at drilling platform above sea level (ft)

a. Potentiometric Elevations may be contoured from a well network to define the potentiometric surface and define directions of fluid flow.

In-Class Problem:

A well with a surface elevation of 1200 ft AMSL is drilled to a depth of 7000 ft with a bottom hole pressure of 2700 psi. The hydrostatic pressure gradient is 0.465 psi/ft; determine the potentiometric surface elevation (elevation to which fluid will rise in well). Show all of your math work and unit algebra.

---

c. Reservoir Pressure Conditions
    i. Normal: pressure gradient = hydrostatic
    ii. Overpressure: > hydrostatic
        1. Artesian conditions
        2. Structural/tectonic compression
    iii. Subnormal: < hydrostatic
        1. Isolated confined aquifers or reservoirs
        2. Overdeveloped sealed reservoirs
        3. Fracturing / fluid loss