Tugas 1: Fisika Batuan

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Importing library

In [3]:
```
# -*- coding: utf-8 -*-
"""
Created on Tue Feb 21 10:24:58 2023

@author: viral
"""
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
```

Defining parameter

In [35]:
```
#MINERAL
#QUARTZ
qrtz_vp = 6037 #m/s
qrtz_vs = 4121 #m/s
qrtz_ds = 2650 #kg/m3
M_qrtz = qrtz_ds*qrtz_vs**2/(10e+8) #GPa
K_qrtz = qrtz_ds*(qrtz_vp**2-(4/3)*(qrtz_vs)**2)/(10e+8) #GPa

#BIOTITE
biot_vp = 5260 #m/s
biot_vs = 2870 #m/s
biot_ds = 3050 #kg/m3
M_biot = biot_ds*biot_vs**2/(10e+8) #GPa
K_biot = biot_ds*(biot_vp**2-(4/3)*(biot_vs)**2)/(10e+8) #GPa

#CLAY
clay_vp = 1500 #m/s
clay_vs = 940 #m/s
clay_ds = 1580 #kg/m3
M_clay = clay_ds*clay_vs**2/(10e+8) #GPa
K_clay = clay_ds*(clay_vp**2-(4/3)*(clay_vs)**2)/(10e+8) #GPa

#FLUID
#WATER
K_wat = 2.25 #GPa
Ds_wat = 1000 #kg/m3

#METHANE
K_met = 0.025 #GPa
Ds_met = 0.68 #kg/m3
```

No.1

In [28]:
```
'''#No. 1'''
#volume fraction
n_step = 0.01
n_biot = np.arange(0, 1+n_step, n_step)
n_qrtz = 1-n_biot
```

```
"""Bounding"""
#Voigt bulk
Kv = (n_biot*K_biot)+(n_qrtz*K_qrtz)
#Reuss bulk
Kr = 1/(((n_biot/K_biot)+(n_qrtz/K_qrtz)))
#Voigt shear
Mv = (n_biot*M_biot)+(n_qrtz*M_qrtz)
#Reuss shear
Mr = 1/(((n_biot/M_biot)+(n_qrtz/M_qrtz)))

#Voigt-reuss hill average
Kvrha = (Kv+Kr)/2
Mvrha = (Mv+Mr)/2

#Hashin Shtrikman
#HS Bulk
Khs_a = K_biot+(n_qrtz/(((K_qrtz-K_biot)**-1)+n_biot*(K_biot+4*M_biot/3)**-1))
Khs_b = K_qrtz+(n_biot/(((K_biot-K_qrtz)**-1)+n_qrtz*(K_qrtz+4*M_qrtz/3)**-1))

#HS Bulk
Mhs_a = M_biot+(n_qrtz/((M_qrtz-M_biot)**-1+(2*n_biot*(K_biot+2*M_biot)/(5*M_biot*(K
Mhs_b = M_qrtz+(n_biot/((M_biot-M_qrtz)**-1+(2*n_qrtz*(K_qrtz+2*M_qrtz)/(5*M_qrtz*(K
```

In [29]:

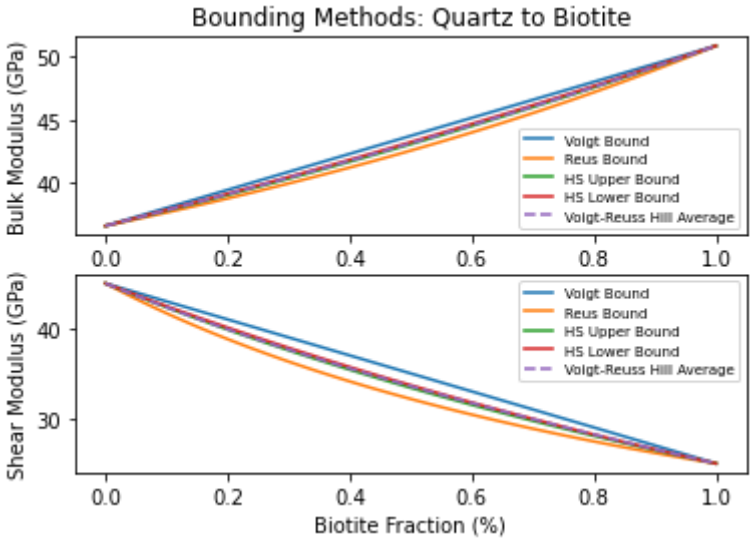
```
fig, axs = plt.subplots(2)

#Axis 1
axs[0].plot(n_biot, Kv, label = 'Voigt Bound')
axs[0].plot(n_biot, Kr, label = 'Reus Bound')
axs[0].plot(n_biot, Khs_a, label = 'HS Upper Bound  ') #KHS_a
axs[0].plot(n_biot, Khs_b, label = 'HS Lower Bound') #KHS_b
axs[0].plot(n_biot, Kvrha, '--', label = 'Voigt-Reuss Hill Average')
axs[0].legend(loc = 'lower right', prop={'size': 7})
#Label and title
axs[0].set_xlabel('Biotite Fraction (%)')
axs[0].set_ylabel('Bulk Modulus (GPa)')
axs[0].set_title('Bounding Methods: Quartz to Biotite')

#Axis 2
axs[1].plot(n_biot, Mv, label = 'Voigt Bound')
axs[1].plot(n_biot, Mr, label = 'Reus Bound')
axs[1].plot(n_biot, Mhs_a, label = 'HS Upper Bound  ') #KHS_a
axs[1].plot(n_biot, Mhs_b, label = 'HS Lower Bound') #KHS_b
axs[1].plot(n_biot, Mvrha, '--', label = 'Voigt-Reuss Hill Average')
axs[1].legend(loc = 'upper right', prop={'size': 7})
#Label and title
axs[1].set_xlabel('Biotite Fraction (%)')
axs[1].set_ylabel('Shear Modulus (GPa)')
```

Out[29]:

```
Text(0, 0.5, 'Shear Modulus (GPa)')
```



No.2

In [30]:

```
'''#No. 2'''
#volume fraction
n_step = 0.01
n_clay = np.arange(0, 1+n_step, n_step)
n_qrtz = 1-n_biot

'''Bounding'''
#Voigt bulk
Kv = (n_clay*K_clay)+(n_qrtz*K_qrtz)
#Reuss bulk
Kr = 1/(((n_clay/K_clay)+(n_qrtz/K_qrtz)))
#Voigt shear
Mv = (n_clay*M_clay)+(n_qrtz*M_qrtz)
#Reuss shear
Mr = 1/(((n_clay/M_clay)+(n_qrtz/M_qrtz)))

#Voigt-reuss hill average
Kvrha = (Kv+Kr)/2
Mvrha = (Mv+Mr)/2

#Hashin Shtrikman
#HS Bulk
Khs_a = K_clay+(n_qrtz/(((K_qrtz-K_clay)**-1)+n_clay*(K_clay+4*M_clay/3)**-1))
Khs_b = K_qrtz+(n_clay/(((K_clay-K_qrtz)**-1)+n_qrtz*(K_qrtz+4*M_qrtz/3)**-1))

#HS Bulk
Mhs_a = M_clay+(n_qrtz/((M_qrtz-M_clay)**-1+(2*n_clay*(K_clay+2*M_clay)/(5*M_clay*(K
Mhs_b = M_qrtz+(n_clay/((M_clay-M_qrtz)**-1+(2*n_qrtz*(K_qrtz+2*M_qrtz)/(5*M_qrtz*(K
```

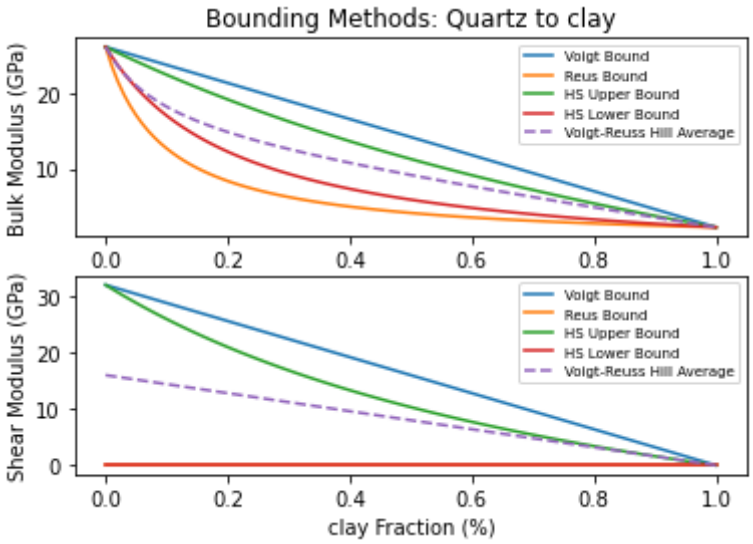
In [39]:

```
fig, axs = plt.subplots(2)

#Axis 1
axs[0].plot(n_clay, Kv, label = 'Voigt Bound')
axs[0].plot(n_clay, Kr, label = 'Reus Bound')
axs[0].plot(n_clay, Khs_a, label = 'HS Upper Bound  ') #KHS_a
axs[0].plot(n_clay, Khs_b, label = 'HS Lower Bound') #KHS_b
axs[0].plot(n_clay, Kvrha, '--', label = 'Voigt-Reuss Hill Average')
axs[0].legend(loc = 'upper right', prop={'size': 7})
#Label and title
axs[0].set_xlabel('clayite Fraction (%)')
axs[0].set_ylabel('Bulk Modulus (GPa)')
axs[0].set_title('Bounding Methods: Quartz to clay')
```

```
#Axis 2
axs[1].plot(n_clay, Mv, label = 'Voigt Bound')
axs[1].plot(n_clay, Mr, label = 'Reus Bound')
axs[1].plot(n_clay, Mhs_a, label = 'HS Upper Bound  ') #KHS_a
axs[1].plot(n_clay, Mhs_b, label = 'HS Lower Bound') #KHS_b
axs[1].plot(n_clay, Mvrha, '--', label = 'Voigt-Reuss Hill Average')
axs[1].legend(loc = 'upper right', prop={'size': 7})
#Label and title
axs[1].set_xlabel('clay Fraction (%)')
axs[1].set_ylabel('Shear Modulus (GPa)')
```

Out[39]: Text(0, 0.5, 'Shear Modulus (GPa)')



No.3

In [36]:

```
'''No 3'''

"""Bounding"""
#Volume fraction
step = 0.01
por = np.arange(0,1+step, step) #Porosity of rock
mat = (1-por)#Fraction volume of matirix

'''Voigt-Reuss'''
#Matrix moduli
K_mix = (0.3*K_clay)+(0.7*K_qrtz)
M_mix = (0.3*M_clay)+(0.7*M_qrtz)

#Bulk
Kv = (por*K_wat)+(mat*K_mix)
Kr = ((por/K_wat)+(mat/K_mix))**-1

#Shear
Mv = (por*0)+(mat*M_mix)
Mr = np.zeros(101)

#Voigt-reuss hill average
Kvrha = (Kv+Kr)/2
Mvrha = (Mv+Mr)/2

'''Hashin-Sthrikman'''
arr_K = [K_mix, K_wat]
arr_M = [M_mix, 0]

#Bulk modulus
```

```
#upper bounds
Khs_a = ((por/(K_wat+(4/3)*max(arr_K)))+(mat/(K_mix+(4/3)*max(arr_K))))**-1-(4/3)*ma
#Lower bounds
Khs_b = ((por/(K_wat+(4/3)*min(arr_K)))+(mat/(K_mix+(4/3)*min(arr_K))))**-1-(4/3)*mi

#Shear modulus
Lmb_max = (max(arr_M)/6)*((9*max(arr_K)+8*max(arr_M))/(max(arr_K)+2*max(arr_M)))
Lmb_min = 0

Mhs_a = ((por/Lmb_max)+(mat/(Lmb_max+max(arr_M))))**-1-Lmb_max
Mhs_b = np.zeros(101)
```

In [38]:

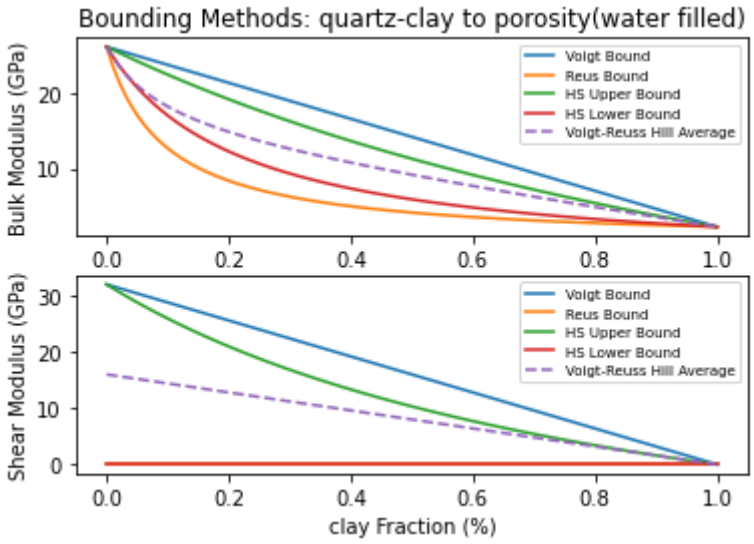
```
"""plot"""
fig, axs = plt.subplots(2)

#Axis 1
axs[0].plot(por, Kv, label = 'Voigt Bound')
axs[0].plot(por, Kr, label = 'Reus Bound')
axs[0].plot(por, Khs_a, label = 'HS Upper Bound  ') #KHS_a
axs[0].plot(por, Khs_b, label = 'HS Lower Bound') #KHS_b
axs[0].plot(por, Kvrha, '--', label = 'Voigt-Reuss Hill Average')
axs[0].legend(loc = 'upper right', prop={'size': 7})
#Label and title
axs[0].set_xlabel('clayite Fraction (%)')
axs[0].set_ylabel('Bulk Modulus (GPa)')
axs[0].set_title('Bounding Methods: quartz-clay to porosity(water filled)')

# #Axis 2
axs[1].plot(por, Mv, label = 'Voigt Bound')
axs[1].plot(por, Mr, label = 'Reus Bound')
axs[1].plot(por, Mhs_a, label = 'HS Upper Bound  ') #KHS_a
axs[1].plot(por, Mhs_b, label = 'HS Lower Bound') #KHS_b
axs[1].plot(por, Mvrha, '--', label = 'Voigt-Reuss Hill Average')
axs[1].legend(loc = 'upper right', prop={'size': 7})
#Label and title
axs[1].set_xlabel('clay Fraction (%)')
axs[1].set_ylabel('Shear Modulus (GPa)')
```

Out[38]:

```
Text(0, 0.5, 'Shear Modulus (GPa)')
```



No. 4

In [40]:

```
'''No 4'''

"""Bounding"""
```

```
#Volume fraction
step = 0.01
por = np.arange(0,1+step, step) #Porosity of rock
mat = (1-por)#Fraction volume of matirix

#modified condition:
por = por/0.4
mat = 1-por

'''Voigt-Reuss'''
#Matrix moduli
K_mix = (0.3*K_clay)+(0.7*K_qrtz)
M_mix = (0.3*M_clay)+(0.7*M_qrtz)

#Bulk
Kv = (por*K_wat)+(mat*K_mix)
Kr = ((por/K_wat)+(mat/K_mix))**-1

#Shear
Mv = (por*0)+(mat*M_mix)
Mr = np.zeros(101)

#Voigt-reuss hill average
Kvrha = (Kv+Kr)/2
Mvrha = (Mv+Mr)/2

'''Hashin-Sthrikman'''
arr_K = [K_mix, K_wat]
arr_M = [M_mix, 0]

#Bulk modulus
#upper bounds
Khs_a = ((por/(K_wat+(4/3)*max(arr_K)))+(mat/(K_mix+(4/3)*max(arr_K))))**-1-(4/3)*ma
#Lower bounds
Khs_b = ((por/(K_wat+(4/3)*min(arr_K)))+(mat/(K_mix+(4/3)*min(arr_K))))**-1-(4/3)*mi

#Shear modulus
Lmb_max = (max(arr_M)/6)*((9*max(arr_K)+8*max(arr_M))/(max(arr_K)+2*max(arr_M)))
Lmb_min = 0

Mhs_a = ((por/Lmb_max)+(mat/(Lmb_max+max(arr_M))))**-1-Lmb_max
Mhs_b = np.zeros(101)


por = np.arange(0,1+step, step) #porisity for plotting
```

In [41]:

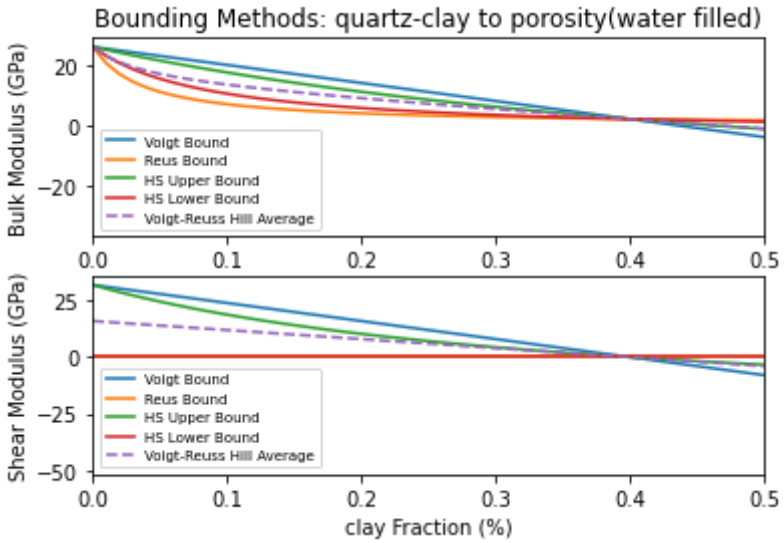
```
"""plot"""
fig, axs = plt.subplots(2)

#Axis 1
axs[0].plot(por, Kv, label = 'Voigt Bound')
axs[0].plot(por, Kr, label = 'Reus Bound')
axs[0].plot(por, Khs_a, label = 'HS Upper Bound  ') #KHS_a
axs[0].plot(por, Khs_b, label = 'HS Lower Bound') #KHS_b
axs[0].plot(por, Kvrha, '--', label = 'Voigt-Reuss Hill Average')
axs[0].legend(loc = 'lower left', prop={'size': 7})
#Label and title
axs[0].set_xlabel('clayite Fraction (%)')
axs[0].set_ylabel('Bulk Modulus (GPa)')
axs[0].set_title('Bounding Methods: quartz-clay to porosity(water filled)')
axs[0].set_xlim([0, 0.5])

# #Axis 2
```

```
axs[1].plot(por, Mv, label = 'Voigt Bound')
axs[1].plot(por, Mr, label = 'Reus Bound')
axs[1].plot(por, Mhs_a, label = 'HS Upper Bound  ') #KHS_a
axs[1].plot(por, Mhs_b, label = 'HS Lower Bound') #KHS_b
axs[1].plot(por, Mvrha, '--', label = 'Voigt-Reuss Hill Average')
axs[1].legend(loc = 'lower left', prop={'size': 7})
#Label and title
axs[1].set_xlabel('clay Fraction (%)')
axs[1].set_ylabel('Shear Modulus (GPa)')
axs[1].set_xlim([0, 0.5])
```

Out[41]: (0.0, 0.5)



No. 5

In [42]:

```
#dataframe making
df = df = pd.DataFrame({'por':por, 'Mv':Mv, 'Mrv':Mr, 'Kv':Kv, 'Kr':Kr})
df_30 = df.iloc[[30]]

df_30
```

Out[42]:

	por	Mv	Mrv	Kv	Kr
30	0.3	7.980406	0.0	8.215123	2.916234

perhitungan belum selesai.