User-defined compaction curves

Compaction curves define the decrease in porosity of a given lithology with increasing burial depth. In Move™, the **2D Kinematic** and **3D Kinematic** modules use compaction curves to calculate the change in stratigraphic thickness following deposition of the uppermost horizon. Accurately compensating for physical compaction is of key importance during a sequential restoraton workflow. For example, the position of the regional sedimentary level may be underestimated by not fully accounting for compaction within a basin.

In Move2017, **user-defined compaction curves** can be created or loaded. These curves allow greater integration of raw geological data into compaction calculations and provide flexibility when defining the response of a horizon during decompaction. In this feature, the theory behind compaction curves will be introduced and workflows which illustrate how to create and apply user-defined curves will be demonstrated.

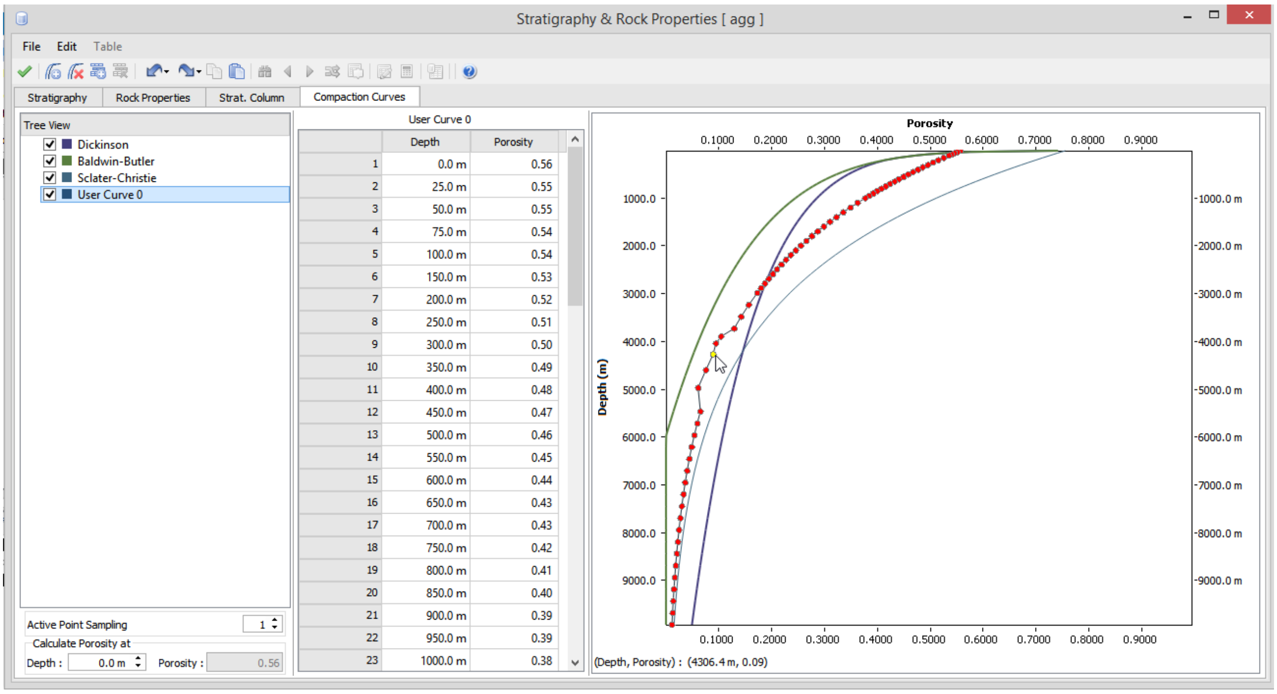


Figure 1: Stratigraphy & Rock Properties database showing the Compaction Curve tab in Move2017. Three default and one user-defined compaction curves are displayed. A node on the user-defined is being manually edited.

Default compaction curves

Move includes three default compaction curves (Figure 1), with each defining a different relationship between porosity and depth. These industry-standard equations, named Sclater-Christie, Baldwin-Butler and Dickinson after their original authors, were derived empirically by fitting exponential or power law curves to extensive porosity/depth datasets:

1. **Sclater-Christie:** a negative exponential curve with greatest porosity loss occurring at shallow depths (Athy, 1930; Sclater and Christie 1980). In the Sclater-Christie equation, porosity (φ) at a given depth (z) is defined by:

$$\varphi(z) = \varphi_0 e^{-cz}$$

where, φ_0 is the depositional porosity of a lithology and c is the depth coefficient.

2. **Baldwin-Butler:** a power-law curve for shales (Baldwin and Butler, 1985). In the Baldwin-Butler equation, burial depth (z) is defined by:

$$(z) = z_{max} s^{\alpha}$$

where, z_{max} is the maximum burial depth in kilometres, s = solidity = $1.0 - \varphi$ and α is the solidity exponent. For normal shales and limestones, Baldwin and Butler (1985) used z_{max}=6.02 and α = 6.35.

3. **Dickinson:** a power-law curve for undercompacted shales. Baldwin and Butler (1985) proposed that for shales >200 m thick, the parameters defined in Dickinson (1953) should be used, where z_{max}=15 and α = 8.

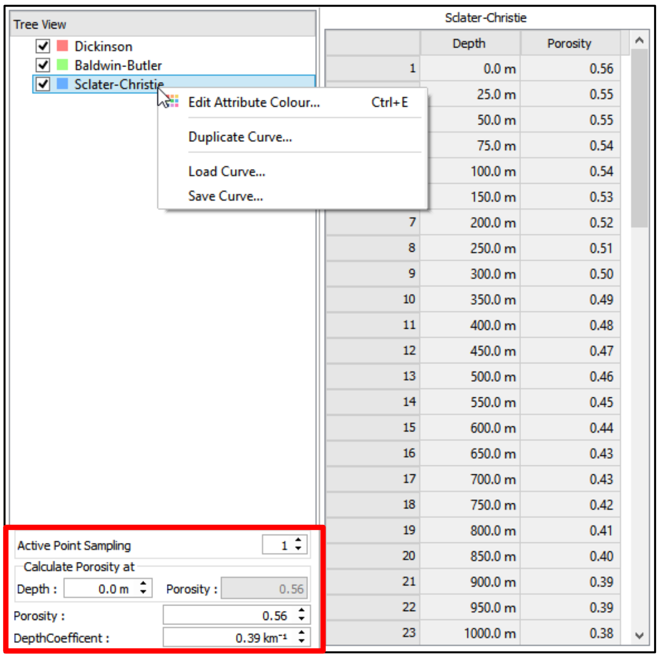


Figure 2: Compaction Curve tree view and table showing the context menu for the Sclater-Christie curve.

In Move, compaction curves are located within the **Compaction Curves** tab of the **Stratigraphy & Rock Properties** database. Alternatively, they can be accessed directly by clicking **Compaction Curves** on the **Data & Analysis** tab in Move.

By default, the Dickinson, Baldwin-Butler and Sclater-Christie curves are plotted and listed in the **Tree View** (Figure 1 and 2). A context menu can be accessed for each curve by right-clicking on the curve title (Figure 2).

Values for depth and porosity are listed in the centre of the Compaction Curve window. Precise depth/porosity relationships can be calculated using the controls at the bottom-left of the window (red box, Figure 2).

User-defined compaction curves

In Move2017, user-defined compaction curves can be created in four ways: 1) Assigning a Sclater-Christie curve to a horizon; 2) Creating and manually adjusting a new curve; 3) Duplicating and manually adjusting pre-existing curves, and 4) Loading in a curve from an external source.

1. Assigning a Sclater-Christie curve:

1. Open the **Rock Properties** database from the **Data & Analysis** tab.
2. Navigate to column **10: Compaction Curve**.
3. In one of the cells of the table, double-click and then click on the down arrow to show the default compaction curve options (Figure 3).
4. Click on Sclater-Christie (Figure 3).
5. Click on the **Compaction Curve** tab.
6. A new curve labeled: **Sclater-Christie (Sandstone)** will have been added to the **Tree View**.

7. Note that the new curve has the Initial Porosity and Depth Coefficient listed in the Rock Properties database.

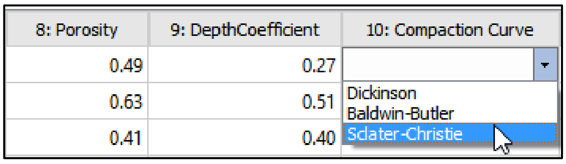


Figure 3: Assigning Sclater-Christie curve to a default Sandstone in the Rock Properties database.

8. The Initial Porosity and Depth Coefficient can be adjusted directly in the Rock Properties database.
9. Alternatively, the values can be adjusted by selecting **Sclater-Christie (Sandstone)** on the Compaction Curve tab and changing the parameters using the controls on the bottom-left of the window (Figure 4).

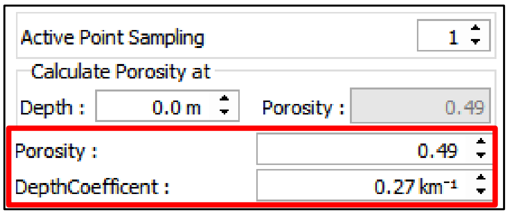


Figure 4: Sclater-Christie controls.

2. Creating and manually adjusting a new curve:

1. Click on **Compaction Curves** on the **Data & Analysis** tab.
2. Navigate to the **Create User Curve** option on the toolbar at the top of the window (Figure 5).
3. A new, linear curve has been created (**User Curve 0)**.
4. Select the curve in the **Tree View**.
5. A series of red nodes will be visualized.
6. Right-click and manipulate a node to a desired Porosity/Depth relationship (Figure 6).

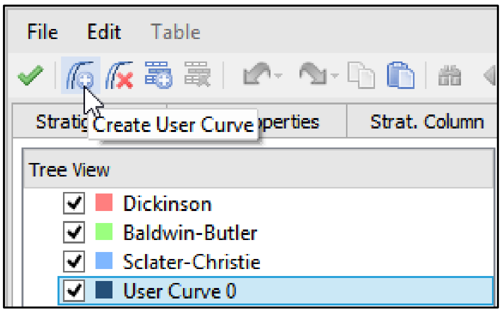


Figure 5: Creating a new user-defined curve.

Note: A node can be deleted by clicking on it with the **middle mouse button**.

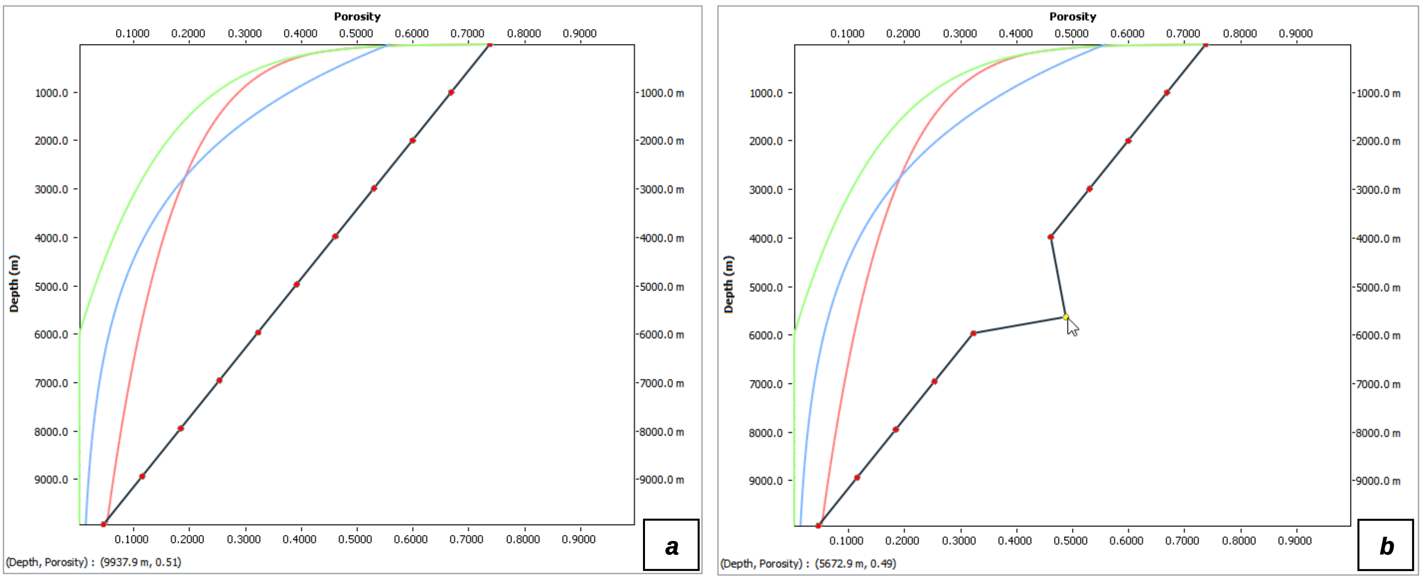


Figure 6: a) Highlighted User Curve 0. b) Adjusted User Curve 0.

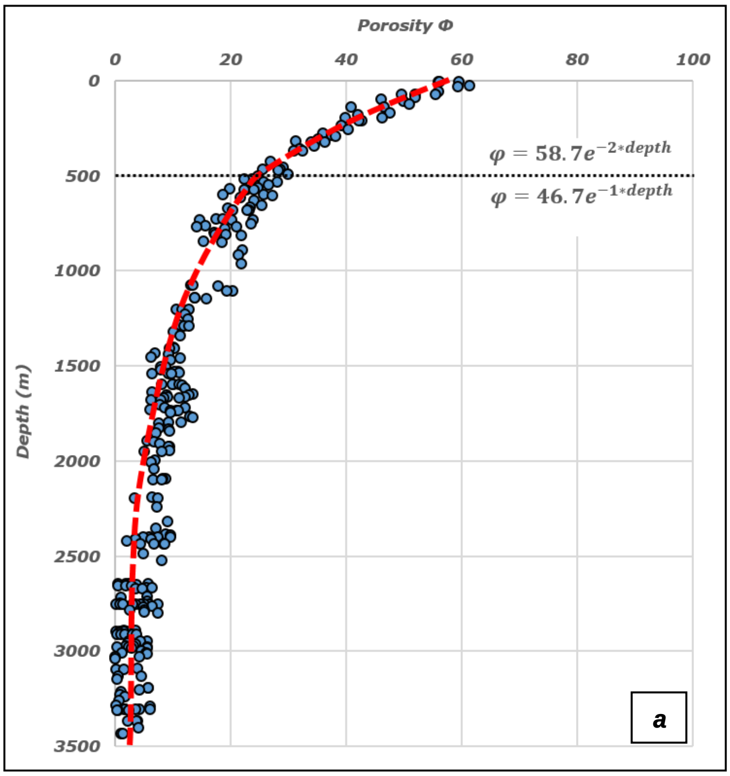
3. Duplicating and manually adjusting a curve:

1. Click on **Compaction Curves** on the **Data & Analysis** tab.

2. Right-click on the Sclater-Christie curve and select **Duplicate Curve** (Figure 2).
3. A new exponential curve has been created (**Sclater-Christie_1).**
4. This curve can be selected and adjusted in the same way as a new curve (Figure 6). The Initial Porosity and Depth Coefficient can be adjusted using the controls on the bottom-left of the window (Figure 4)

4. Loading a new curve from an external source:

Porosity data for a given depth can often be derived or estimated from down-well petrophysics. In the example presented in Figure 7, best-fit curves have been added to a plot of porosity data. Two different exponential curves have been used above and below 500 m depth (Figure 7a). The decimated and merged depth/porosity data can then be exported from a spreadsheet in plain ASCII format (Figure 7b).




```
Depth,Porosity
0,0.5876
25,0.55894241
50,0.531682467
75,0.505752007
100,0.481086191
125,0.45762334
150,0.435304786
175,0.414074722
200,0.393880059
225,0.374670302
250,0.356397416
275,0.339015709
300,0.322481717
325,0.306754098
350,0.291793525
375,0.277562586
400,0.264025699
425,0.251149014
450,0.238900332
475,0.227249025
500,0.283431777
525,0.276433822
550,0.269608646
575,0.262951985
600,0.256459678
625,0.250127666
650,0.243951991
```

b

Figure 7: a) Porosity/depth data with fitted curve. b) ASCII porosity/depth data for red line in Fig 7a.

1. Click on **Compaction Curves** on the **Data & Analysis** tab.
2. Right-click on the **Tree View** and select **Load Curve…**.
3. Select the desired ASCII dataset.
4. Load curve using ASCII loader (Figure 8).

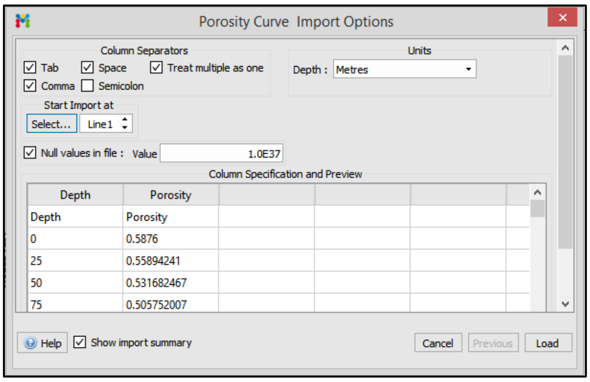


Figure 8: ASCII loader showing data from Figure 7b.

5. A new curve: **Compaction Curve** is added to the **Tree View** (Figure 9).
6. Double-click to rename the curve.
7. The curve can be edited in the same way as new or duplicated curves.

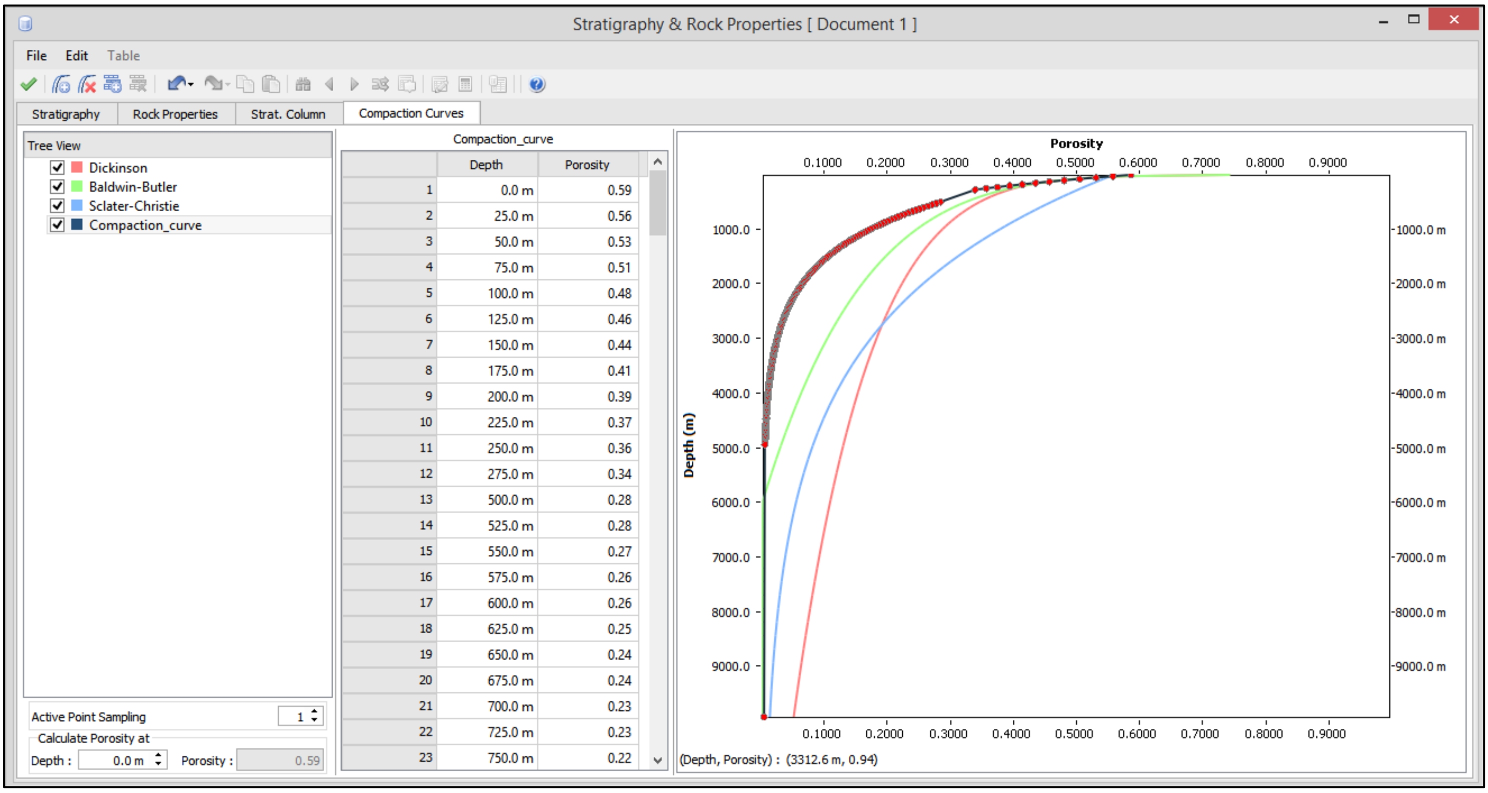


Figure 9: Loaded compaction curve for red line shown in Figure 7a.

User-defined compaction curves, irrespective of how they were created, can be assigned to a horizon in the **Rock Properties** database. These curve will be used to calculate the change in thickness of that horizon when using the **Decompaction** tool in the **2D Kinematic** or **3D Kinematic Modelling** modules, increasing the accuracy of the restoration workflow.

References

Athy, L. F., 1930, Density, porosity, and compaction of sedimentary rocks: *AAPG Bulletin*, v. **14**, p. 1-24.

Baldwin, B., and C. O. Butler, 1985, Compaction curves: *AAPG Bulletin*, v. **69**, p. 622–626.

Dickinson, G., 1953, Geological aspects of abnormal reservoir pressures in Gulf Coast, Louisiana: *AAPG Bulletin*, v. **37**, p. 410–432.

Sclater, J. G., and P. A. F. Christie, 1980, Continental stretching: An explanation of the Post-Mid-Cretaceous subsidence of the central North Sea Basin: *Journal of Geophysical Research: Solid Earth*, v. **85**, p. 3711–3739.