Algorithm Advice

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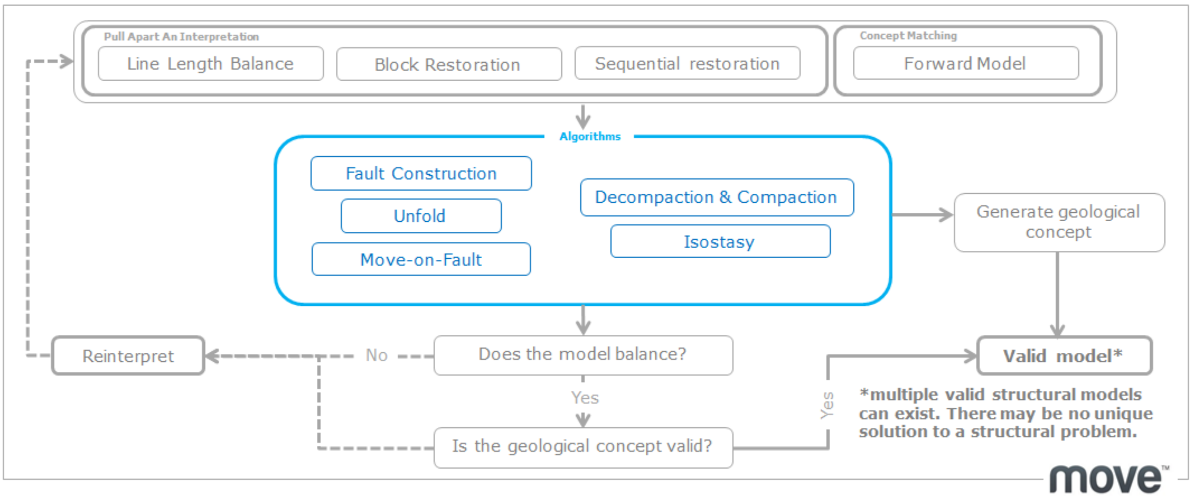
This document contains a brief overview of the workflows and algorithms available inside the Move™ software suite and their key applications.

Algorithms are simplified models of the geometric and mechanical processes that produce geological structures during deformation. The exact algorithm used should be determined by the mechanics of the individual horizons and boundary conditions. It is important to understand that a model might be restorable with different algorithms and thus will show slightly different restored geometries. Therefore, a restored model does not necessarily represent an exact pre-deformation geometry or the path followed by the structural evolution.

The main workflows and algorithms within Move are summarised in the diagram below.



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Workflows

- Testing of geological concepts and ideas requires the problem to be defined, a work strategy and also the level acceptable errors needs to be taken into consideration. To develop a work strategy we need to ask ourselves the "what if…" question and use structural modelling as a tool to test ideas. Best practice uses a variety of restoration algorithms to establish sensitivity and to develop an understanding of deformation history.

Workflow	Overview	Algorithm
Line length and surface area balance	First pass quick analysis unfolding.	Line Length Unfolding Flexural Slip Unfolding Simple Shear Unfolding
Block Restoration and Jigsaw Fitting	Validation technique, fitting fault blocks together in Map and Section view. It can also be used for rigid block restoration.	Flexural Slip Unfolding Simple Shear Unfolding With manual transformation (Jigsaw Fitting)
Sequential restoration	Shows the intermediate stages between fully deformed and fully restored. Provides insights into the structural evolution and is a more rigorous test. Growth stratigraphy (thickness change) area shown as intermediate stages.	Flexural Slip Unfolding Simple Shear Unfolding Simple Shear (inclined or vertical) Fault Parallel Flow Fault Bend Fold Decompaction Isostasy
Forward Modelling	Deformation of the hanging wall is the result of movement over a fault plane. Try to test ideas about how the section got to the present-day state.	Simple Shear (inclined or vertical) Fault Parallel Flow Trishear Fault Bend Fold Fault Propagation Fold Detachment Fold Compaction Isostasy

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Fault Construction

Fault construction techniques are based on the principle that deformation observed in the hanging wall is controlled by the geometry of the fault across which it moved. The shape of a horizon can therefore be used to predict the geometry of the fault that controlled its deformation. Depth to detachment methods are based on area balance. These construction algorithms can be used to:

- Predict fault geometry at depth;
- Define detachment depth.

Algorithm	Overview	Application
Constant Heave 2D	Based on the principles outlined by White *et al.* (1986). An assumption is made that the shape of folds in the hanging wall is derived from the movement along a fault.	Listric fault construction. In some situations these methods can also be applied to inverted and compressional systems.
Constant Slip 2D	Based in the work of Williams and Vann (1987), the algorithm moves the hanging wall along displacement trajectories parallel to the fault surface (fault parallel flow).	
Constant Bed Length 2D	Based on the principles discussed by Davison (1985). The method assumes that flexural slip folding occurs within the hanging wall and implies that net slip on the fault decreases with increasing fault depth.	
Simple Depth to Detachment 2D	Calculated using the area balance method of Hassack (1979); the area between the regional, hangingwall and the fault plane is equal to the area of extension or contraction.	Extensional, shorting or inversion regimes.
Area-Depth Method 2D	Modified from the Area-Depth method of Groshong (1994); horizon elevation relative to original horizon height is plotted to predict the detachment.	
Move-On-Fault Algorithms	Can use used interactivity to adjust fault geometries to match data which defines hanging wall geometry.	Refer to Move-On-Fault table.

References

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Unfolding

Unfolding can be used as a quick first-order check for line length inconsistencies, and allows quantitative predictions to be made about a region's geological history or as a step during a sequential restoration to remove deformation. Unfolding can be used to:

- Identify locations where horizons are missing or incorrectly interpreted;
- Quantify tectonic shortening or extension through time;
- Restore deformation for example by unfolding to regionals;
- Capture strain which can be used as a proxy for fracture models.

Algorithm	Overview	Application
Line Length 2D	Simply the length of the line.	Identify missing or incorrectly interpreted horizons. Quantify tectonic shorting or extension through time.
Horizontal Length 2D	Horizontal length from the start and end of each line. Does not maintain line length or volume.	Quantify the amount of extension in a basin.
Simple Shear 2D / 2.5D	Layer deformed by penetrative, closely spaced slip planes, using a vertical or inclined shear vector. Maintains area and volume but not line length.	Use to maintain area and volume but not line length. Typically used for extensional regimes and in areas of salt tectonics.
Flexural Slip 2D / 2.5D	Layer parallel slip between the beds. Analogous to flexing a package of papers.	Use to maintain area / volume and line length. Typically used for fold and thrust belts, inversion structures and in areas of salt tectonics.
Geomechanical 3D	Mass Spring algorithm; an iterative numerical technique designed to minimise the strain within a solid body while attempting to retain its original shape.	Well suited to modelling geological structures because it mimics natural forces using physical laws of motion. It does not require that a fully water tight model is built as with finite element models.

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Bourguignon, D. and Cani, M., 2000., Controlling Anisotropy in Mass-Spring Systems: *Proceedings of the Eleventh Eurographics Workshop on Computer animation and Simulation, Springer Computer Science,* 113-123.

Move-on-Fault

Move-on-Fault algorithms are kinematic algorithms that aim to mimic the mechanisms of deformation seen in the field, measured from geometric relationships of structures. The exact algorithm you use should be determined by mechanics of the individual horizons and boundary conditions.

Simple Shear, Fault Parallel Flows and Trishear can all be used to model both shorting and extensional structures, whereas Fault Bend Fold, Detachment Fold and Fault Propagation Fold are used to mimic shorting structures. They are very powerful tools for guiding interpretation, understand deformation history and in 3D for creating inputs for advanced modelling (for example for basin modelling and / or sediment modelling and geotechnical studies; as fracture proxies). Amongst other things, forward modelling and restorations may:

- Highlight mis-picked horizons and give ideas about how to adjust hanging wall volumes;
- Show issues with fault linkage and give a guide to correct fault displacements;
- Help guide interpretation of data;
- Provided concepts for the geological evolution of an area.

Algorithm	Overview	Application
Block Restoration 2D / 2.5D	Transformation (rotation and translation) are used to restore offsets along faults.	Used when there is no internal deformation expected within faulted blocks. Forward modelling and restoration.
Simple Shear 2D / 2.5D	Models the relationship between fault geometry and hanging wall deformational features. Simple Shear, models deformation where deformation is diffuse throughout the hanging wall rather than discrete slip between beds as in flexural slip.	Most applicable to extensional tectonic regimes, where anticlinal rollover structures have developed on non-planar normal faults. Can be applied to the restoration or forward modelling of inverted basins and growth faults, where the thickness of beds may vary. Forward modelling and restoration.
Fault Parallel Flow 2D / 2.5D	Based on the continuing work of Egan *et al.* (1997) and is based on Particulate Laminar Flow over a fault ramp. Particles in the hanging wall translate along flow lines, which are parallel to the fault plane.	Best suited for modelling hanging wall movement on faults from fold and thrust belts where the majority of the deformation occurs discretely between bed interfaces (flexural slip). Forward modelling and restoration.

Fault Bend Fold 2D / 2.5D	Based on the work of Suppe (1983a) and based on the principle that deformation in the hanging wall reflects the geometry of the underlying fault.	Forward modeling of fault bend folds and associated growth strata and the effects of erosion.
Detachment Fold 2D	Based on the work of Poblet & McClay (1996) and used for folds that form above blind thrusts where horizontal displacement becomes vertical. Detachment folds can take a variety of geometries including kink band, chevron and box detachment folds.	Forward modelling in contractional settings in which a thick ductile layer (such as salt or shale) takes up the accommodation space produced during deformation.
Fault Propagation Fold 2D	Incorporates the work of Suppe & Medwedeff (1990), beds in the trailing limb will maintain layer thickness whilst those in the forelimb may thicken or thin as the fault advances and the beds rotate. One the fault has passed through a horizon it will experience no further footwall deformation. The algorithm allows both constant bed thickness and fixed-axis models to be produced whilst maintaining the properties of self-similar growth band migration.	Forward modelling contractional structures in which forelimb deformation proceeds the advancing fault tip and hanging wall geometries mirror that of the fault. Used to model the association of asymmetric folds with one steep or overturned limb to thrust faults.
Trishear 2D / 2.5D	Developed in collaboration with Colorado State University (Erslev, 1991). It models geological structures by deforming beds within a triangular zone of shear emanating from the tip of a propagating fault.	Modelling fault-related folds of extensional or shorting structures. Can be used as alternative to models for fault-related folds. Forward modelling and restoration.

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Decompaction

The subsidence of a sedimentary basin can be attributed to four processes: tectonic subsidence**,** water and sediment loading, thermal subsidence and sediment compaction. The aim of backstripping is to analyse subsidence history by progressive reversal of the depositional process. Part of the backstripping process is to account for sediment compaction. Backstripping removes from each sedimentary layer the effects of: sediment compaction, water and sediment loading.

- Provides valid palinspastic sections through time giving true stratigraphic thicknesses;
- Better indications on volume and area changes of units though time;
- Better indications on subsidence history.

Algorithm	**Overview**	**Application**
Sclater-Christie **2D / 2.5D**	Based on the work of Sclater & Christie (1980); it assumes that porosity decreases with increasing depth (Compaction) and increases with decreasing depth (Decompaction).	The standard method for areas of mixed sediments.
Baldwin-Butler **2D / 2.5D**	Based on the work of Baldwin and Bulter (1985).	This is most appropriate when working with shales.
Dickinson **2D / 2.5D**	Based on the work of Dickinson (1953).	This is most appropriate when working with shales over 200 m thick (overpressured).
Isostasy only **2D / 2.5D**	Model the effects of isostasy on the section without including decompaction.	Refer to Isostasy table.

References

Sclater, J.G., and Christie, P.A.F. 1980. Continental stretching: an explanation of the post-Mid-Cretaceous subsidence of the Central North Sea Basin. *Journal of Geophysical Research,* **85**, 3711-3739.

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Dickinson, G. 1953. Geological aspects of abnormal reservoir pressures in Gulf Coast Louisiana. *The American Association of Petroleum geologists Bulletin,* **37**, 410-432.

Isostasy

Isostasy is the theoretical equilibrium that exists in the Earth's crust. If this equilibrium is disturbed, for example, as a result of erosion or deposition, compensatory movements in the Earth's crust occur. It is important from regional to field scale as it affects:

- Restored shape of horizons and faults which are important for geometries of traps;
- Palaeo-topographies, important for sediment modelling predict erosion;
- Absolute heights of horizons during restoration, important for maturation studies.

Algorithm	Overview	Application
Airy Isostasy 2D / 2.5D	Assumes a brittle crust floating on a fluid layer. The crust is of finite strength and cannot support its own weight and the crust has no strength. It produces a vertical movement (i.e. no flexure). This theory is backed by evidence from deep seismic refraction surveys and mountains underlain by thick crust and oceans by thin crust.	Loads that have consistent lateral thickness; not applicable in sections with laterally variable loads. Salt restoration.
Flexural Isostasy 2D / 2.5D	Assumes the crust has an inherent strength and rigidity causing it to flex as a load is applied. How much the crust deforms is controlled by: a) elastic thickness, b) load and mantle density and c) the Young's Modulus. This theory is backed by evidence from isolated volcanoes like Hawaii and flexural uplift of areas adjacent to loads such as mountains, producing foreland basins.	Loads that have variable lateral thickness. Tectonic loads: Sedimentary basins, mountain belts and foreland areas. To defined its control on sequence thicknesses, onlap/offlap relationships, subsidence, uplift and erosion. As a rule of thumb, when the dimensions of the model are >15 km or as factor of elastic and thickness and flexural wavelength.

References
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