Glossary of fault and other fracture networks

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Abstract
Increased interest in the two- and three-dimensional geometries and development of faults and other types of fractures in rock has led to an increasingly bewildering terminology. Here we give definitions for the geometric, topological, kinematic and mechanical relationships between geological faults and other types of fractures, focussing on how they relate to form networks.

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1. Introduction

The large amount of work on faults, joints, veins and other fractures over the last few decades has led to the introduction of many new terms and some confusing terminology. Even the simple term fracture has itself become confusing and misused, tending to be used so generally that geological significance can disappear, as discussed by Manda and Horsman (2015). Referring to a fracture in rock can be like saying a person has a pet mammal – strictly true, but so vague as to be meaningless. Is the fracture a fault, joint, vein or dyke? Is the mammal a cat, capybara, honey badger or marmoset?

In this glossary, we focus on the relationships between different fractures and how they interact with each other and form fracture networks (Fig. 1). We give terms related to: a) different fracture types, b) relationships between fractures, c) fracture geometries, kinematics and mechanics. We attempt to show how the different terms are related to each other and to highlight key differences between terms. Although we suggest that the term fracture is too vague for geological analysis, we use fracture to denote where a term is applicable to a range of fracture types, e.g., faults, joints, veins. We give “fault or other type of fracture” in the definitions to avoid misunderstanding. This is to highlight similarities between different structures. In these cases, appropriate references are provided for each fracture type. For some terms, however, use of fracture is appropriate, e.g., conductive fracture. We also focus on structural discontinuities that are not fractures per definition (e.g., stylolites and deformation bands), but that are included for completeness. Where usage has changed through time, we provide examples of current usage.

The glossary is intended to be useful for structural geologists and other scientists working on fault or other type of fracture networks. The terms in this glossary cover three main categories (Table 1):

a) Terms used to describe individual fractures and their associated structures. A review of fracture terminology is provided by Schultz and Fossen (2008), whilst similar glossaries for strike-slip faults are given by Biddle and Christie-Blick (1985), for thrusts by Butler (1982) and McClay (1992), and for normal faults by Peacock et al. (2000). We do not cover all words relating to the faults and other types of fracture, both for brevity and to avoid duplicating existing glossaries, with general terms being available in standard textbooks (e.g., Ramsay and Huber, 1987; Price and Cosgrove, 1990; Twiss and Moores, 1992; Fossen, 2010), as are general terms used in structural geology (such as strain and stress). Instead, this glossary focusses on terms relating to networks of faults and other types of fracture. We have attempted to find the first usage, or the earliest reasonable usage, of terms.

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b) Terms used to describe the associations and interactions between two (or more) fractures. Here we seek to establish a consistent and rational set of terms to describe how two or more faults or other types of fractures interact geometrically, kinematically or mechanically, covering a range of structures from relays, through approaching and abutting fractures, to crosscutting fractures (Fig. 2). In this section we attempt to rationalise geometric terms dealing with fractures in general and the kinematic interactions of faults (Fig 3). We use the term interaction to describe any relationship whereby the development of one fault or other type of fracture affects others. Two adjacent faults or other types of fractures are said to intersect if their surfaces are connected (geometric linkage), whereas kinematic linkage occurs where displacement is distributed between the faults without physical intersection, as in relay ramps (Peacock and Sanderson, 1991). We generalise the concept of coherency, introduced for fault arrays by Walsh and Watterson (1991), to describe systematic interactions (either geometric or kinematic) in networks of faults.

c) Terms used to describe networks and populations of fractures. Populations of fractures can be described in terms of their frequency, intensity, spacing, and size (length), but networks can also be described by their topology (Sanderson and Nixon, 2015) and through associated graph theory, and the application of percolation concepts. Fig. 4 summarises the node and branch model used by Sanderson and Nixon (2015) to characterise fracture networks with increasing interaction as they pass through the percolation threshold to form a connected network.

We attempt to divide terms into those that are geological, geometric, topological, kinematic and/or mechanical (Fig. 1 and Table 1). This is to show that different terms have particular uses in each step of an analysis.

1.1. Geological

Here we use the adjective geological for nouns that describe features observed in rock that do not necessarily have direct geometric, kinematic or mechanical significance. Examples include fault, fracture, joint, vein, etc.

1.2. Geometric

Geometry is defined by OxfordDictionaries.com (2015, http://www.oxforddictionaries.com/definition/english/geometry) as “the branch of mathematics concerned with the properties and relations of points, lines, surfaces, solids, and higher dimensional analogues”. In the context of faults or other types of fractures, geometry refers to the size, shape and orientation of individual faults or other types of fractures and to the patterns formed by different faults or other types of fractures. Here we use the adjective geometric to describe the shapes or patterns of geological features.

1.3. Topological

Topology describes the arrangement of and geometric relationships between spatial objects such as faults and other fractures. Topological characterisation generally involves using components, such as nodes and branches, and dimensionless parameters that are invariant to scale, strain and continuous transformations (Jing and Stephansson, 1997; Sanderson and Nixon, 2015). We use the adjective topological to help describe the geometric arrangements of faults and other fractures. Whilst topological terms are not currently in common usage within structural geology, we include them because they represent useful ways for describing the characteristics of networks.

1.4. Kinematic

Kinematics is defined by OxfordDictionaries.com (2015, http://www.oxforddictionaries.com/definition/english/kinematics) as “the branch of mechanics concerned with the motion of objects without reference to the forces which cause the motion”. Here we use the adjective kinematic to refer to terms that relate to displacement, and strains associated with the development of geological features.
1.5. Mechanical

Here we use the adjective mechanical to refer to terms that describe the processes by which geological features have formed or to the mechanical properties of the rock mass produced by fractures.

2. Glossary

An alphabetic list of the terms used, along with other relevant terms and approximate synonyms, are given here. Our preferred terms are shown in Fig. 1. Each of these terms are geological structures that can form networks, or are related to the geometries, topologies, kinematics or mechanisms of fault and other fracture networks in rock.

A

Abutting fault or other type of fracture [geometric]: a fault or other type of fracture that meets another at an intersection line or point (Fig. 2a). This is a geometric term and does not signify a developmental relationship between the faults or other types of fractures, e.g., they could have originally been two different faults or other types of fractures that met or intersected, or one may have splayed off the other. Abutting relationships have been described for faults (Nixon et al., 2014) and joints (Rives et al., 1994).

Alteration zone [geological]: an area of mineralisation, commonly associated with hydrothermal fluids, faults and economic deposits (e.g., Lee and Wilkinson, 2002; Sutherland et al., 2012). The term chemical alteration zone is used by Thienprasert et al. (1991) and by Kristensen et al. (accepted).

Anastomosing [geometric]: based on the definition of anastomosis by OxfordDictionaries.com (2015, http://www.oxforddictionaries.com/definition/english/anastomosis), anastomosing would be the geometry whereby adjacent channels, tubes, fibres, or other parts of a network are cross-connected. Anastomosing geometries have been described for faults (Rowe et al., 2013), joints (Singh, 1992), veins (Philipp, 2008) and dykes (Valentine and van Wyk de Vries, 2014).

Anticrack [geological and mechanical]: see styloite.

Antithetic fault [geometric and kinematic]: originally defined as a minor fault that dips in the opposite direction to the dip direction of the beds they displace (Cloos, 1928; Hills, 1940, Fig. 41). Antithetic fault is now commonly used for a fault that has the opposite shear sense to a related dominant fault or fault set (e.g., Gibbs, 1984). See synthetic fault and conjugate.

Aperture [geometric]: the width of a fracture measured perpendicular to the walls, i.e., the amount of extension across the fracture. Synonymous with thickness of veins (Vermilye and Scholz, 1995) and dykes (e.g., Jolly and Sanderson, 1995). Joint apertures are discussed by Hooker et al. (2009).

Approaching fault or other type of fracture [geometric]: where a fault or other type of fracture has propagated towards and interacts with, another fault or other type of fracture, but the two faults or other types of fractures do not intersect (Fig. 2a). This term is valid for both parallel faults and faults at angles to each other. Examples of approaching faults are shown by Flodin and Aydin (2004, Fig. 1), approaching (and connected) joints are shown by Noroozi et al. (2015, Fig. 8), and approaching veins are shown by Virgo et al. (2014, Fig. 10).

Approaching damage zone [kinematic and mechanical]: defined by Peacock et al. (in review) as the area of deformation related to interaction between two or more faults that do not intersect (Fig. 5). It is a type of interaction damage zone and is intended to be a more general term than the linking damage zone of Kim et al. (2004). Also see damage zone.

Architecture [geological]: defined by OxfordDictionaries.com (2015, http://www.oxforddictionaries.com/definition/english/architecture) as “the art or practice of designing and constructing buildings ...” The style in which a building is designed and constructed, especially with regard to a specific period, place, or culture ... The complex or carefully designed structure of something ... The conceptual structure and logical organisation of a computer or computer-based system”. The term is now used in sedimentology to denote the geometry of sedimentary rocks and facies (e.g., Marzo et al., 1988). The term is being used increasingly in structural geology, apparently to denote the geometries of structures (e.g., O’dea and Lister, 1995).

Arrangement, network [topological]: the spatial layout of lines or planes in a network, that may or may not be connected to each other. Topological description considers the network as a system of topological components (e.g., nodes and branches), e.g., which indicate the relationships and connectivity of faults and other fractures within a network (e.g., Jing and Stephansson, 1997; Adler and Thovert, 1999). Also see topology, node and branch.

Array, fault or other type of fracture [geometric and kinematic]: a set of stepping or en echelon faults or other type of fracture segments or fault or other type of fracture zones. Arrays are common geometries for faults (e.g., Segall and Pollard, 1980), joints (e.g., La Pointe and Hudson, 1985), veins (e.g., Rothery, 1988) and dykes (e.g., Brown et al., 2007, Fig. 1). Vein arrays are synonymous with tension gashes.

B

Backbone [topological]: the connected lines or planes within a network, i.e., that are composed entirely of doubly-connected branches or C–C branches (Fig. 4), e.g., a system of connected faults or other fractures. The backbone has the potential to allow flow or transport across a spanning cluster and thus is commonly used as a qualitative and quantitative descriptor in percolation theory (e.g., Stanley, 1977; Sahimi, 1994; Aizenman, 1997; Manzocchi, 2002; Hunt et al., 2014). Also see doubly-connected branch, cluster, spanning cluster, percolation theory.

Bed-bound fault or other type of fracture [geometric and mechanical]: see layer-bound fault or other type of fracture. Also see mechanical stratigraphy.

Bimodal [geometric]: fault or other type of fracture pattern forming two sets of planes with dip directions or strikes that exhibit a two-fold symmetry (e.g., Woodcock and Underhill, 1987; Healy et al., 2015). This pattern is commonly associated with faults and other fractures that formed under a plane strain (Anderson, 1951; Reches, 1978). Synonymous with conjugate.

Block [geometric]: a body of rock bounded entirely, or in plane-view, by faults (e.g., Versey, 1927) or other fractures (e.g., Rawnsley et al., 1998). Also see horst.

Branch [topological]: a line that is bound by nodes at each end (Fig. 4), e.g., a fault trace. There are three types of branch: isolated branches (1–1), singly-connected branches (1–C), and doubly-connected branches (C–C) (e.g., Sanderson and Nixon, 2015).

Branch [geometric]: verb for where one or more faults or other types of fractures extend off a larger fault or other type of fracture, typically used for faults (e.g., Nevin, 1931; Butler, 1982). Branch line [geometric]: the line along which two fault planes connect in when viewed in 3D (Butler, 1982). It appears not to be commonly used for other types of geological fractures. Whilst we use intersection line to keep our terminology consistent and applicable to other fracture types, we do not suggest that branch line be replaced as a term for faults.
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**Branch point [geometric]:** the point at which two fault traces branch or splay when viewed in 2D. Thrust branch points are described by McClay (1992). To keep our terminology consistent and applicable to other fracture types, we use intersection point. Synonymous with connecting node.

**Breccia [geological]:** defined by OxfordDictionaries.com (2015, http://www.oxforddictionaries.com/definition/english/breccia) as a “rock consisting of angular fragments of stones cemented by finer calcareous material”. Other minerals can form cements, including quartz and gypsum. Non-sedimentary breccias consist of vein networks, including hydrothermal breccias (e.g., Jębrak, 1997) and fault breccias (e.g., Woodcock and Mort, 2008).

**Bridge, fault or other type of fracture [geometric and kinematic]:** block of rotated rock between stepping and interacting extension fractures (e.g., Kemeny, 2005). Bridges have been described for joints (e.g., Yan et al., 2007), veins (e.g., Laing, 2004) and dykes (e.g., Platten, 2000). Also see broken bridge.

**Brittle fault or other type of fracture [mechanical]:** defined by OxfordDictionaries.com (2015, http://www.oxforddictionaries.com/definition/english/brittle-fracture) as a “fracture of a metal or other material occurring without appreciable prior plastic deformation”. Brittle structures and the geometries and mechanics of brittle deformation are described in detail in various structural geology textbooks (e.g., Ramsay, 1967; Ramsay and Huber, 1987). Note that “semi-brittle faults” also occur (e.g., Chester, 1989).

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<th>Fracture networks and populations</th>
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Fig. 2. (a) Different types of intersections between fractures and (b) related topological terms. Green circles represent I-nodes, red triangles represent the connections between two fractures (i.e., between three branches, topologically), while blue squares represent the connections between crossing fractures (i.e., between four branches, topologically). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 3. Diagram representing different types of interaction between fractures.

Fig. 4. The node and branch model used by Sanderson and Nixon (2015) to characterise fracture networks with increasing interaction as they pass through the percolation threshold ($P_c$) to form a connected network.
Broken bridge [geometric and kinematic]: a bridge across which two extension fractures have geometrically linked (e.g., Schofield et al., 2012).

Cataclasis [geological and mechanical]: process involving brittle fragmentation of minerals or grains, with rotation of grain fragments, grain boundary sliding, grain flaking and fracturing, grain size reduction, and commonly volume change (Sibson, 1977). Cataclasis typically occurs along fault planes, within fault zones, or within deformation bands.

Clastic dyke [geological]: used for fractures filled by sedimentary rocks (e.g., Jolly et al., 1998). Some clastic dykes infill from the surface (termed neptunian dyke), whilst others form by injection of fluidised sediment fed from below (e.g., Kenkmann, 2003). Also known as injectite or sedimentary dyke.

Closed fracture [geological]: used to describe fractures in the sub-surface which have zero porosity (e.g., Wu and Pollard, 2002), e.g., because they are sealed by minerals. See non-conductive fracture.

Cluster [topological]: a group of interconnected lines or planes within a network, usually made up of a backbone (doubly-connected branches) and dangling ends (singly-connected branches), e.g., a system of link faults. These can be either an isolated cluster or a spanning cluster (Stanley, 1977; Aizenman, 1997; Odling et al., 1999). Cluster has also been applied geologically to a group of faults or other type of fractures that produce a certain spatial distribution or arrangement, e.g., that are closely-spaced or have the same orientation (Bour and Davy, 1999; Manzocchi, 2002). Also see isolated cluster and spanning cluster.

Coherence, geometric [geometric]: the existence of regular and systematic displacement patterns in arrays or networks of faults. The concept was originally applied to zones of normal faults with splays and relays (Walsh and Watterson, 1991, Fig. 4), but can be extended to domains within fault networks, including cases where different types of faults combine to produce systematic patterns (Fig. 3).

Coherence, kinematic [kinematic]: the existence of displacement distributions that are arranged such that geometric coherence is maintained (Walsh and Watterson, 1991).

Compartment [geometric]: a block in which the fluids are sealed from adjacent blocks by faults (e.g., Knipe, 1997), commonly identified adjacent compartments having distinct fluid pressures or chemistries. Also see block, horse and lens.

Compartmentalisation [geometric]: the geometry whereby a rock mass is divided into compartments, or the process by which compartments develop (e.g., Clark et al., 2012).

Conductive fracture [geological]: a fracture within which fluids flow (Olsson et al., 1992), or that is identified by electrical conductivity on borehole image logs (e.g., Samantray et al., 2010). Note that some open fractures may be electrically non-conductive (e.g., Boutt et al., 2010). See open fault or other type of fracture. Antonym of non-conductive fracture.

Conjugate [geometric and kinematic]: for faults, conjugate refers to the relationship between two intersecting sets of faults (or joints) that each formed under the same stress field (Daubrée, 1878; cited by Dennis, 1967). Two conjugate faults have the opposite shear sense and the same angle (generally ~ 30°) to the maximum principal stress direction (Anderson, 1951). Intersecting conjugate faults may move alternately (Freund, 1974; Horsfield, 1980), or may move synchronously to form an area of high strain near the intersection (Peacock, 1991; Odonne and Massonnet, 1992). Pairs of conjugate faults can consist of a larger fault and a smaller antithetic fault. Also see antithetic fault and synthetic fault.

Connecting fault or other type of fracture [geometric and kinematic]: connects two stepping faults or other types of fractures (e.g., Peacock and Sanderson, 1994). Synonymous with connecting splay (Ramsay and Huber, 1987, Fig. 23.50b); for faults, the term breaching fault is synonymous (Miller, 1999; Peacock and Parfitt, 2002). Connecting geometries have been described for faults (e.g., Cruikshank et al., 1991) and dykes (e.g., Zák et al., 2012).

Connecting node [topological]: the point of connection between two lines, i.e., X-nodes and Y-nodes (Manzocchi, 2002; Nixon et al., 2012; Sanderson and Nixon, 2015). Synonymous with intersection point. See also Nodes.

Connectivity [geometric and topological]: the degree to which faults or other types of fractures are connected within a network, which depends on the size, frequency, orientation, spatial correlation, scaling and topology of the (Berkowitz et al., 2000;
Manzocchi, 2002). Connectivity has been described for a range of structures, including faults (e.g., Cherpeau et al., 2011), veins (e.g., Virgo et al., 2014), joints (e.g., Alghalandis et al., 2015), stylolites (Ben-Izhak et al., 2014) and deformation bands (Sternlof et al., 2004). Also see critical connectivity. Corridor, fracture [geometric]: tabular zone of significantly-increased fracture intensity (e.g., Questiaux et al., 2010; Gabrielsen and Braathen, 2014). Also see swarm, fault or other type of fracture. Coupling [kinematic]: defined by Oxford Dictionaries.com (http://www.oxforddictionaries.com/definition/english/coupling) as “the pairing of two items”. Coupling, geometric [geometric]: where one fault or other type of fracture intersects or crosses another fault or other type of fracture, i.e., where two faults or other types of fractures are physically connected - synonymous with geometrical linkage (cf. Chambon and Rudnicki, 2001). Coupling, kinematic [kinematic]: where the displacements, stresses and strain of one fault or other type of fracture influences those of another fault or other type of fracture. Synonymous with kinematic linkage. Crack [geological]: defined by the Oxford English Dictionary (1989) as being “a fissure or opening formed by the cracking, breaking, or bursting of a hard substance”, with first usage attributed to Palsgrave (1530). The term appears to be used synonymously with fault or other type of fracture (e.g., Zhao et al., 2007), particularly in the engineering literature. The term crack has no particular mechanical implications, so includes any type of fracture. Critical connectivity [topological]: the average number of intersections per fracture needed to reach the percolation threshold, at which a spanning cluster first forms within a network (e.g., Robinson, 1983, 1984; Balberg and Binenbaum, 1983; Manzocchi, 2002). Also see percolation threshold and spanning cluster. Crossing fault or other type of fracture [geometric]: a fault or other type of fracture that cuts and displaces another fault (e.g., Chen, 2013) or fracture (Fig. 2a).

D Damage zone [kinematic and mechanical]: location at which a major change in fabric (e.g., caused by pressure solution) is readily visible (Chester and Logan, 1986; Wu and Groshong, 1991), or the volume of deformed wall rocks around a fault surface that results from the initiation, propagation, interaction and build-up of slip along faults (Cowie and Scholz, 1992; McGrath and Davison, 1995; Kim et al., 2004; Choi et al., in press). Synonymous with deformation front and texture zone (Wu and Groshong, 1991). Dangling end [topological]: a line or cluster of lines that is connected to the rest of the cluster only at one end, the other end being a tip or I-node (Fig. 4) (Stanley, 1977; Hunt et al., 2014). Thus these are unable to carry flow through the network unlike the backbone (Sahimi, 1994; Hunt et al., 2014). Also see singly-connected branch, backbone, cluster, isolated cluster and spanning cluster. Deformation band [geological]: a mm-scale tabular zone of localized but non-discrete strain (Friedman and Logan, 1973; Engelder, 1974), typically involving grain reorganisation (grain sliding and rolling), cataclasis (grain flaking, fracturing and crushing) and/or dissolution or precipitation (e.g., Aydin, 1978; Knott, 1994). They typically occur in porus granular rock types. Note that there are wide range of terms related to deformation bands, including compactional shear band (Fossen et al., 2007), compactive shear band (Aydin et al., 2006), cataclastic deformation band (Wibberley et al., 2000), cataclastic slip band (Fowles and Burley, 1994), compaction band (Mollema and Antonellini, 1996; Rotevatn et al., 2016), dilatant shear band (Aydin et al., 2006), dilation band (Du Bernard et al., 2002), disaggregation band (Fossen et al., 2003), disaggregation zone (Knipe, 1986), framework-phylloliscic structures/band (involving 10–40% phyllosilicate minerals; Fisher and Knipe, 1998), granulation seam (e.g., Pittman, 1981), isochoric shear band (Aydin et al., 2006), Luder’s bands (Friedman and Logan, 1973), phyllosilicate/clay smear (involving >40% phyllosilicate minerals; Fisher and Knipe, 2001), shear band (Menendez et al., 1996), shear-enhanced compaction band (Eichhubl et al., 2010), slipped deformation band (Rotevatn et al., 2008), solution band (Gibson, 1998), solution and cementation band (Fossen et al., 2007). Density, fault or other type of fracture [geometric]: see intensity, fault or other type of fracture. Desiccation crack [geological]: an opening mode fracture formed by contraction of soft sediment, usually clay or mud, as it dries (e.g., Lister and Secrest, 1985). Also called mud crack. Dilatome [geological]: pipe-like shaped plug of breccia and igneous rock produced by explosive intrusion (e.g., White and Ross, 2011). Dimensionless intensity [geometric and topological]: a dimensionless measure derived from the product of the fault or other type of fracture intensity and the average line or branch length (Robinson, 1983; Balberg and Binenbaum, 1983; Manzocchi, 2002; Sanderson and Nixon, 2015). It is scale invariant and provides a useful indication of connectivity (Sanderson and Nixon, in review), with critical values that indicate the percolation threshold, at which a spanning cluster first forms within a network. Also see percolation threshold and spanning cluster. Dip-linkage [geometric and kinematic]: the along-dip, or vertical, linkage of two faults or other types of fractures that were initially geometrically uncoupled (Mansfield and Cartwright, 1996). Dip-slip [kinematic]: the component of displacement parallel to the dip of the fault plane (cf. strike-slip) (Reid et al., 1913). Normal, reverse and thrust faults are all dip-slip faults. Discontinuity [geological and mechanical]: a surface across which there is a variation in the mechanical behaviour of rocks, such as bedding planes or fractures (e.g., Fookes and Parrish, 1969). Domain [geological, geometric and kinematic]: in this context, a volume, area or region of rock with distinct geometries, kinematics or mechanics of geological structures (e.g., Schlische and Withjack, 2009; Nixon et al., 2011; Zhu et al., 2013). Domino faults [geometric and kinematic]: a system of planar rotating normal faults, in which the dip of a particular stratigraphic datum is approximately constant (e.g., Twiss and Moores, 1992). Synonymous with bookshelf faults (e.g., Ramsay and Huber, 1987, Fig. 23.19) and with rotational planar normal faults of Wernicke and Burchfied (1982). Doubly-connected branch [topological]: a line with connecting nodes at both ends, thus often referred to as a C–C branch (Sanderson and Nixon, 2015; Morley and Nixon, 2016), e.g. a fault trace that connects with other faults at both ends. Also see topology, isolated branch, singly-connected branch, connecting node. Synonymous with backbone. Also see lens. Duplex [geological and geometric]: an arrangement of faults with the same shear sense that are geometrically- and kinematically-linked to form a series of lensoidal or sigmoidal horses, i.e., each pair of faults has two intersection points in map- or section-view. Duplexes have been described for thrust (e.g., Butler, 1982), normal (e.g., Gibbs, 1984) and strike-slip (Woodcock and Fischer, 1986) faults.
Dyke (or dike) [geological]: defined by the Oxford English Dictionary (1989) as “a mass of mineral matter, usually igneous rock, filling up a fissure in the original strata”, with first use accredited to Playfair (1802). The term is now most commonly used for a fault or other type of fracture at a high angle to bedding that is filled by intrusive igneous rock (e.g., Paquet et al., 2007), not necessarily following a pre-existing fault or other type of fracture (e.g., Delaney and Pollard, 1981). Dykes and sills open because the internal pressure of the magma exceeds the least compressive stress in the surrounding rocks (e.g., Pollard, 1987), with the least compressive stress being sub-horizontal for a sub-vertical dyke to form. The fault or other type of fracture utilised by the magma may be a pre-existing feature or a new fault or other type of fracture created by the overpressured magma (Pollard, 1987). Dyke networks are described by Jolly and Sanderson (1995).

E

En echelon [geometric]: defined by Biddle and Christie-Blick (1985) as “a stepped arrangement of relatively short consistently overlapping or underlapping structural elements such as faults or folds that are approximately parallel to each other but oblique to the linear or relatively narrow zone in which they occur”. En echelon patterns have been described for faults (e.g., Hempton and Neher, 1986), joints (e.g., Bahat, 1986), veins (e.g., Beach, 1975), dykes (e.g., Weinberger et al., 2000) etc. Extension(al) fault [kinematic]: see normal fault. Extension(al) fracture [kinematic]: a fracture that has opened up at a high angle to the fracture plane, with the fracture usually inferred to be perpendicular to the least, and parallel to the maximum and intermediate, compressive stress axes (e.g., Smith, 1997). Extension fractures can therefore include dykes, sills, joints and veins. Extension fractures usually form when the fluid pressure exceeds the compressive stress perpendicular to the fracture plane (e.g., Jaeger, 1969). Also known as tension fracture (Bucher, 1920; Gudmundsson, 1995). Also see mode I. See Pollard and Aydin (1988, p. 1186).

F

Fault linkage [kinematic and mechanical]: see linkage. Fault [geological, kinematic and mechanical]: defined by the Oxford English Dictionary (1989) as being “a dislocation or break in continuity of the strata or vein”, with first usage being attributed to Bakewell (1813). Price (1966) defines a fault as “a plane of fracture which exhibits obvious signs of differential movement of the rock mass on either side of the plane. Faults are therefore planes of shear failure”, i.e., they are planes along which there has been movement parallel to the plane. More recent work has shown that faults are usually zones, having a volume that includes interacting and linked segments, breccias and fault rocks (e.g., Davatzes and Aydin, 2003; Childs et al., 2009). See Zone, fault. Fault zone [geometric]: see zone, fault. Finite cluster [topological]: see isolated cluster. Fissure [geological]: defined by the Oxford English Dictionary (1989) as “a cleft or opening (usually rather long and narrow) made by splitting, cleaving, or separation of parts”. With reference to geology, the Oxford English Dictionary define fissure-vein as “a fissure in the earth’s crust filled with mineral”, with Geikie (1882) being cited. Fissure is used in volcanology for an open fracture developed at the Earth’s surface above a dyke (e.g., Pollard et al., 1983), for fault-related open fractures developed at the Earth’s surface in basalt (e.g., Martel and Langley, 2006), and to describe open fractures in volcanic rocks at the Earth’s surface (e.g., Paquet et al., 2007). We suggest that the term be limited to open fractures of unknown origin that reach the Earth’s surface. Flower structure [geometric]: a system of faults that splay upward within a strike-slip fault zone (Harding and Lowell, 1979). Negative flower structures involve steepening upwards extensional splay faults, whereas positive flower structures involve shallowing upwards contractional splay faults (Harding, 1983, 1985). Fracture [geological and mechanical]: defined by the Oxford English Dictionary (1989) as “the action of breaking or fact of being broken … The result of breaking; a crack, division, split; a broken part, a splinter … The characteristic appearance of the fresh surface in a mineral, when broken irregularly by the blow of a hammer”. The first usage for the fresh surface of a mineral is attributed by the Oxford English Dictionary (1989) to Sullivan (1794). Pollard and Aydin (1988) suggest fracture should be used as a general term for structure without preserved evidence for the mode of fracturing, i.e., it is applicable to structures formed by extension or shear. Geological fractures can include such approximately planar discontinuities as dykes, faults, joints and veins, and the term appears to be synonymous with discontinuity (e.g., Priest and Hudson, 1976, 1981). Pollard and Aydin (1988) state that, lacking information about the mode of displacement, “geologists should avoid speculative interpretations and refer to the structures simply as fractures”. We agree, but suggest that fracture is only used when the origin or style of fracture is unknown. Frequency, fault or other type of fracture [geometric]: see intensity, fault or other type of fracture.

G

Geometric coherence [geometric]: the existence of regular and systematic displacement patterns in a family of faults (Walsh and Watterson, 1991, Fig. 4). Geometric coupling [geometric]: where two fracture planes share an intersection line (or branch line), i.e., the two are physically connected (e.g., Jackson and Rovetta, 2013). Also see hard-linkage. Geometric linkage [geometric]: where two faults or other types of fractures are connected at an intersection line. The faults or other types of fractures need not have kinematic linkage, e.g., if one fault or other type of fracture post-dates and cuts the other without effects on the geometry or displacement pattern. Granulation seam [geological]: see deformation band.

H

Hard-linkage [geometric and kinematic]: the geometry or process whereby two faults are connected by one or more (usually smaller) faults which are visible at the scale of observation (Walsh and Watterson, 1991). See connecting faults, hard-linkage and soft-linkage. Horse [geometric]: a fault-bound body of rock (e.g., Butler, 1982). Also see block. Horsetail [geometric and kinematic]: Biddle and Christie-Blick (1985) define a horsetail splay as “one of a set of curved fault splays near the end of a strike-slip fault that merge with that fault. The set forms an array that crudely resembles a horse’s tail”. The term need not be restricted to strike-slip faults. Also see pinnate. Hybrid fracture [kinematic and mechanical]: a fracture that developed by synchronous Mode I and shear modes (e.g., Ramsey and Chester, 2004).
Hydrofracture [mechanical]: fracture created by fluid pressures that exceed the applied stresses to cause “effective tension” (e.g., Price and Cosgrove, 1990). The process of “hydraulic fracturing” (also called “hydrofracking” or “fracking”) is commonly used to enhance recovery of hydrocarbons (e.g., Mandl and Harkness, 1987). Also see induced fracture. Hydrothermal [geological]: relating to the activities hot fluids (i.e., higher than the expected geothermal gradient) in rock, including alteration (e.g., Uglow, 1913), metamorphism (e.g., Naboko, 1963), mineralisation (e.g., Sapykin, 1967) and brecciation (e.g., Katz et al., 2006).

Intersection damage zone [geometric, kinematic and mechanical]: we define this as the area of deformation around the intersection point of two or more faults. Peacock et al., in review. Also see approaching damage zone, damage zone, and linking damage zone. Intersection line [geometric]: the line along which two fault or other type of fracture planes meet. Approximately synonymous with branch line. Used for deformation bands (e.g., Stel, 1991), faults (e.g., Maerten et al., 2000), etc. We prefer intersection line to branch line because it is based on geometry and implies no origin, i.e., it can be used if it is not known whether one fault or other type of fracture branched off another, or whether they were originally unconnected. Intersection point [geometric]: the point at which two fault or other type of fracture traces meet. Approximately synonymous with branch point, which is used for faults. Used for faults (e.g., Kelly et al., 1998), lineaments (e.g., Bagheri, 2015), etc. We prefer intersection point to branch point because it is based on geometry and implies no origin, i.e., it can be used if it is not known whether one fault or other type of fracture branched off another, or whether they were originally unconnected. Intersection, fault or other type of fracture [kinematic]: the process by which, condition in which, or location at which, two originally separate faults or other types of fractures become physically connected. It is therefore synonymous with the term linkage as used by Pollard and Aydin (1984). Intersection is preferred to linkage, however, because the term linkage appears to have become limited to refer to connection between sub-parallel faults or other types of fractures (e.g., Kim et al., 2004), e.g., linkage across relay ramps (e.g., Peacock and Sanderson, 1991). Described for dykes (e.g., Caldwell and Young, 2013), faults (Spotila and Anderson, 2004), fractures (e.g., Reks and Gray, 1982) and veins (e.g., Anderson and Nash, 1972).

Isolated branch [topological]: a line with two unconnected ends (i-nodes), e.g., a fault or other type of fracture trace that has isolated tips at both ends (Fig. 4) (Ortega et al., 2006; Sanderson and Nixon, 2015). Synonymous with isolated fault or other type of fracture. Also called finite cluster. Also see singly-connected branch, doubly-connected branch, node, connecting node and topology. Isolated cluster [topological]: a group of interconnected faults or other types of fractures that form a cluster that is not large enough to provide a pathway across a sample area (Roberts et al., 1998; Sahimi, 2011). They are often referred to as finite clusters and do not have the potential to percolate, unlike a spanning cluster (Sahimi, 1994; Aizenman, 1997; Hunt et al., 2014). Also see cluster and spanning cluster.

Isolated fault or other type of fracture [geometric and kinematic]: a fault or other type of fracture that was not affected by interaction with other faults or other types of fractures during its propagation (for isolated faults, see Muraoka and Kamata, 1983; Walsh and Watters, 1987). An isolated fault is usually characterised by a displacement maximum near the centre of the fault trace, with displacement decreasing approximately linearly towards the tips (Barnett et al., 1987; Walsh and Watters, 1987). Harding and Lowell (1979) describe solitary structures that are isolated, singular features. Nicol et al. (1996) describe unrestricted faults, that are blind (do not intersect the free surface) and that have not interacted with other faults or with substantial bodies of incompetent rock. The traces of such isolated faults or other types of fractures would show two i-nodes.

Joint [geological]: defined by the Oxford English Dictionary (1989) as “a crack or fissure intersecting a mass of rock;
usually occurring in sets of parallel planes, dividing the mass into more or less regular blocks”, with first usage attributed to Holland (1601). Price (1966) defines joints as “cracks and fractures in rock along which there has been extremely little or no movement”, with some authors describing shear joints having a shear displacement (e.g., Hancock, 1985). Pollard and Segall (1987) show that joints have two parallel surfaces that meet at the fracture front, that these surfaces are approximately planar, and that the relative displacement of originally adjacent points across the fracture is small compared to fracture length. Pollard and Aydin (1988) suggest that joints are generally associated with the opening mode, whereas faults are associated with the shearing modes, and propose that the word “joint” be restricted to those fractures with field evidence for dominantly opening displacements. We suggest that fractures with dominantly opening displacements but that have mineral fills should be called veins. Pollard and Aydin (1988) criticise definitions of joints as having no discernible displacement, because they would not exist without some displacement. They are particularly critical of the concept of “shear joints”, which they regard as small faults. Pollard and Aydin (1988) define, describe and illustrate various joint geometries (e.g., cross, diagonal, dip, ladder, normal, polygonal and strike joints), mechanisms (e.g., contraction, cooling, shrinkage and unloading joints) and surface patterns (e.g., hackle and rib marks and plumose structures).

K. I.

Kinematic coupling [kinematic]: where the displacements or strains of two or more faults or other types of fractures are related (Tvedt et al., 2013), with or without geometric coupling (e.g., Thomas and Woodcock, 2015). Also see soft linkage.

Kinematic linkage [kinematic]: where displacements or strains of two or more (usually coeval) faults or other types of fractures are related (e.g., Webb and Johnson, 2006). The faults or other types of fractures need not have geometric linkage.

Layer-bound fault or other type of fracture [geometric and kinematic]: fault or other type of fracture that is restricted to a single bed or mechanical layer. Synonymous with bed-bound fault or other type of fracture. See mechanical stratigraphy. Used for deformation bands (e.g., Antonellini and Molloena, 2015), faults (e.g., Cartwright and Lonergan, 1996), joints (e.g. Ketterman et al., 2016), stockworks (e.g., de Vries and Tourret, 2007) etc.

Length [geometric]: the distance between the tips of a fracture, usually measured along a fracture trace and in the horizontal plane (e.g., Scholz and Cowie, 1990). Walsh and Watterson (1988) define fault length as the maximum horizontal distance of a fault plane observed in 3D. A component of connectivity. Joint lengths are described by Odling (1997).

Lens [geometric]: fault-bound zone of relatively weakly-deformed host rock within a fault zone (e.g., Swanson, 2005). Also called shear lens (e.g., Swanson, 1990). Also see horse.

Lineament [geological]: defined by Biddle and Christie-Blick (1985) as “a linear topographic feature of regional extent that is thought to reflect crustal structure”. Linkage, fault or other type of fracture [kinematic and mechanical]: a general term for the situation in which two originally separate (usually coeval) faults or other types of fractures become connected (Pollard and Aydin, 1984). The connection may be through physical intersection of the fracture surfaces (geometric linkage) or by sharing displacement characteristics (kinematic linkage) in relay ramps or approaching fracture tips (Fig. 3).

Linking damage zone [kinematic and mechanical]: area of deformation at steps between two sub-parallel (usually coeval) faults (Fig. 5) (Kim et al., 2004). This term is therefore more restricted than our term interaction damage zone. Also see damage zone.

M, N

Mechanical stratigraphy [geometric and mechanical]: where the stratigraphy is defined in terms of rheology, such that different mechanical units control the types or frequencies of structures (e.g., Corbett et al., 1987). Also see bed-bound fault or other type of fracture and layer-bound fault or other type of fracture.

Microrack [geometric and mechanical]: fractures with microscopic-scale lengths, apertures, etc. (e.g., Robertson, 1960)

Mode I [mechanical]: fracture propagation by extension (e.g., Atkinson, 1987, Fig. 11). Also see extension fracture, tension fracture and tensile fracture.

Mode II [mechanical]: fault propagation by in-plane shearing or sliding, i.e., perpendicular to the fault tip line (e.g., Atkinson, 1987, Fig. 11). Also see fault.

Mode III [mechanical]: fault propagation by anti-plane shearing or tearing, i.e., parallel to the fault tip line (e.g., Atkinson, 1987, Fig. 11). Also see fault.

Mud crack [geological]: see desiccation crack.

Natural fracture [geological]: fracture resulting from naturally occurring stresses and fluid pressures, i.e., not related to human activities. Antonym of induced fracture.

Neptunian dyke [mechanical]: fracture filled with sediments from the Earth’s surface, e.g., Strachan et al. (1948). Also see clastic dyke and sedimentary dyke.

Network, fault or other type of fracture [geometric]: a system of linked and interacting faults or other types of fractures, more diffuse than a fault or other type of fracture zone (e.g., Stoces and White, 1935). When more than two fault or other type of fracture sets are present, the network represents a triaxial strain system (Reches, 1978; Krantz, 1988). Networks have been described for faults (e.g., Nixon et al., 2014), veins (e.g., Garofalo et al., 2002), joints (e.g., Zhang and Sanderson, 1996) and dykes (Reichardt and Weinberg, 2012, Fig. 17).

Node [topological]: a point where a line ends (I-node) or intersects with another line (X-node or Y-node) (Figs. 2 and 4), e.g., the tip or intersection point of a fault or other type of fracture. Three main types of node can be recognised in fault or other type of fracture networks, representing isolated tips (I-nodes), abutments or splays (Y-nodes), and crossing faults or other types of fractures (X-nodes) (Manzocchi, 2002; Nixon et al., 2012; Sanderson and Nixon, 2015). The proportions of the different node types can be used to characterise the network (Fig. 4d) and calculate topological measures that describe the networks connectivity (e.g., Manzocchi, 2002; Mäkel, 2007; Sanderson and Nixon, 2015).

Non-conductive fracture [geological]: a fracture within which fluids do not flow (e.g., Fransson, 2007), or that in non-conductive to electricity on borehole image logs (e.g., Sanmantray et al., 2010). Note that some open fractures may be electrically non-conductive (e.g., Boutil et al., 2010). See closed fracture. Antonym of conductive fracture.

Normal fault [geological and kinematic]: fault in which the hanging-wall (the fault block sitting above the fault plane) are displaced downwards relative to the footwall (rocks below the fault) (e.g., Dennis, 1967).

O

Oblique [geometric]: lines or planes that are not parallel to each other.
Fracture population analysis involves the study of the scaling area or region, formed during one or more deformation events. Population [geometric]: a network of fractures that has an aperture partly-filled by minerals and partly by fluid (e.g., Wennberg et al., 2016). Percolation [geometric and topological]: describes the phenomenon of fluid flow through a medium (Broadbent and Hammersley, 1957; Sahimi, 1993). For example, a fault or other type of fracture network is said to be percolating when it is macroscopically open and connected to allow flow of fluids through a rock mass (Sahimi, 1994; Adrian and Thouvert, 1999). Pinnate [geometric and kinematic]: extension fracture developed near the tips of shear fractures (e.g., Segall and Pollard, 1983; Crider and Peacock, 2004) to accommodate displacement variations along the shear fractures. Also see horsetail and wing crack. Polyhedral faults [geometric]: a network of faults with no regionally consistent preferred strike orientation (e.g., Lonergan et al., 1998). Layer-bound polygonal faults in the North Sea are described by Cartwright and Lonergan (1996). Polymodal [geometric and kinematic]: pattern of faults or other types of fractures where three, four or more sets form and slip simultaneously (Healy et al., 2015). Such a pattern of faulting is associated with a triaxial strain rather than a plane strain (Reches, 1978; Healy et al., 2015). Also see bimodal and conjugate. Population [geometric]: the fractures of all scales that exist in an area or region, formed during one or more deformation events. Fracture population analysis involves the study of the scaling relationships and strain of the fractures, usually divided into the different deformation events (e.g., Cowie et al., 1996). Pull-apart [geometric and kinematic]: a rhomb-shaped opening along an extensional bend on a fault or at an extensional step between two faults (e.g., Peacock and Anderson, 2012). Process zone [mechanical]: used in material science for an area of micro-cracking at the tip of a propagating fault or other type of fracture, involving non-linear behaviour. Process zones in rock are generally dilational areas (Atkinson, 1987, Fig. 1.4), although process zones in normal fault zones involving compactive shear bands have also been described by Cowie and Shipton (1998) and Rotevatn and Fossen (2012). Also see tip damage zone (Kim et al., 2004). Propagation [mechanical]: increase in length and area of a fault or other type of fracture or fault or other type of fracture zone, commonly involving an increase in displacement. Propagation has been described for dykes (e.g., Okamura et al., 1988), faults (e.g., Walsh and Watterson, 1988; Reches and Lockner, 1994), veins (e.g., Grimm and Orange, 1997) etc.

R Reactivation [kinematic]: renewed displacement on a fault that has undergone a prolonged period of inactivity (e.g., Shepherd-Thorn et al., 1972; Sibson, 1985). The different displacement events may or may not be of the same sense. Also see trailing. Relay pattern [geometric]: an arrangement of overlapping or underlapping sub-parallel faults (e.g., Harding and Lowell, 1979; Biddle and Christie-Blick, 1985, Fig. 2). Relay faults are described by Goguel (1952) and relay ramps between normal faults are described by Larsen (1988). The term does not appear to be applied to other types of fracture. Relay ramp [geometric and kinematic]: zone of kinematic linkage between overlapping, geometrically uncoupled, sub-parallel faults, where strain is relayed from one fault to the other (Larsen, 1988; Peacock and Sanderson, 1991; Rotevatn et al., 2007). If the faults bounding the relay ramp become geometrically coupled, a breached relay (Trudgill and Cartwright, 1994) is formed. Relay zone/structure [geometric and kinematic]: zone of geometric or kinematic linkage between sub-parallel (usually coeval) fault segments (Fossen and Rotevatn, 2016). Encompasses both relay ramps and breached relay ramps. Reverse fault [geological and kinematic]: steeply-dipping fault (usually considered to have a dip of more than 30°), in which the hanging-wall (rocks above the fault) is displaced upwards in relation to the footwall (rocks below the fault) (e.g., Brown, 1984, Fig. 3). Also see thrust fault. Roughness, fault or other type of fracture [geometrical]: measure of the degree to which the fault or other type of fracture surface deviates from planar (e.g., Tsang and Witherspoon, 1983).

S Saturation, joint [mechanical]: where the spacing of a joint set in a bed reaches a narrow unimodal distribution (e.g., Becker and Gross, 1996, Fig. 10). Seal [geological]: a barrier to fluid flow in rock, including rock layers (e.g., Downey, 1984) and faults (e.g., Yielding et al., 1997; Reilly et al., 2016). Sedimentary dyke [geological]: see clastic dyke and neptunian dyke. Segment [geometric]: an individual fault or other type of fracture plane that is part of a set of sub-parallel faults or other types of fractures that together form a fault zone or fracture zone (e.g., Segall and Pollard, 1980). Set, fault or other type of fracture [geometric]: a group of the same type of faults or other types of fractures in a region with the similar orientations and usually inferred to be genetically-related. Used for faults (e.g., Nieto-Samaniego, 1999), joints (e.g., Bai et al., 2002), veins (e.g., Stowell et al., 1999), etc. Shear fracture [mechanical]: fracture formed by modes II and III propagation (e.g., Belayneh and Cosgrove, 2010, Fig. 1). Identified by displaced markers, fault rocks, slickensides, etc. (e.g., Pallister et al., 2013). See fault.
Shear joint [geometric and kinematic]: a joint that displays and was formed by a “minor” shear displacement (e.g., Qidong and Peizhen, 1982). The term is rejected by Pollard and Aydin (1988) because any shear displacement would make the fracture a fault.

Sill [geological]: defined by the Oxford English Dictionary (1989) as “a bed, layer, or stratum of rock, esp. of an intrusive igneous rock. In mod. use, a tabular igneous intrusion lying parallel to the surrounding strata”, with first usage attributed to Hutchinson (1794). The term is now most commonly used for a horizontal fracture (or fracture sub-parallel to layering) filled by intrusive igneous rock (e.g., de Sitter, 1964).

Singly-connected branch [topological]: a line with one connecting node and one isolated node (I-node), thus often referred to as an I–C branch (Sanderson and Nixon, 2015; Morley and Nixon, 2016), e.g. a fault trace that intersects another fault in one direction but with a blind tip in the other direction. Also see topology, branch, isolated branch, doubly-connected branch, connecting node. Synonymous with dangling end.

Slickenside [geological]: a striation along a fault plane caused by displacement along the fault (e.g., Bates and Jackson, 1980). Also called slickenside lineations.

Slickolite [geological]: plane made pressure solution along a fault plane, consisting of ridges and groove or half columns that fit into the ridges and groove on the opposite face of the plane (e.g., Nitecki, 1962). They commonly form along pre-existing discontinuities oriented obliquely to the maximum compressive stress direction (e.g., Sinha-Roy, 2002). Also see stylolite.

Slip plane [geological]: used in material science for a plane along which displacement may occur (e.g., Dennis, 1967). Used in geology for a surface along which displacement has occurred (e.g., Stewart and Hancock, 1991). Synonymous with fault plane.

Slip surface [geological and mechanical]: see fault plane and slip plane.

Slip vector [kinematic]: the direction of motion of one wall of a fault relative to the other wall of that fault (e.g., Reid et al., 1913).

Soft-linkage [kinematic]: where there is a kinematic coherency between faults that are geometrically uncoupled, achieved by distributed strain of the wall-rocks, i.e., there is no linkage by faults visible at the scale of observation (Walsh and Watterson, 1991). A relay ramp (e.g., Larsen, 1988) is an example of soft-linkage, across which strain is relayed between adjacent (but geometrically uncoupled) faults. Also see hard-linkage.

Spacing, fault or other type of fracture [geometric]: the distance between faults or other type of fracture traces or planes, normally measured perpendicular to the faults or other types of fractures. Studies on spacing have been carried out on faults (e.g., Brooks et al., 1996; Sharples et al., in press), joints (e.g., Narr and Suppe, 1991; Rabinovitch et al., 2012) and veins (e.g., Van Noten and Sintubin, 2010).

Spanning cluster [topological]: a group of interconnected lines that together form a cluster large enough to span a sample area (Fig. 4), e.g., faults or other types of fractures that are connected such that they cross an area of interest (Roberts et al., 1998; Sahimi, 2011). They are often referred to as infinite clusters and have the potential to percolate (Sahimi, 1994; Aizenman, 1997; Hunt et al., 2014). Also see cluster and isolated cluster.

Splay fault [geometric]: one or more smaller faults that join a larger fault to which it is related (e.g., Biddle and Christie-Blick, 1985, Fig. 2). The larger fault “splays” if it is connected with one or more splay faults (de Sitter, 1956).

Step, fault or other type of fracture [geometric]: see overstep, fault or other type of fracture.

Stockwork [geological]: a network of veins formed from several sets or randomly orientated veins (e.g., Linnen and Williams-Jones, 1987).

Strand [geological]: defined by Biddle and Christie-Blick (1985) as “an individual fault of a set of closely spaced parallel or sub-parallel faults of a fault system”.

Strike-linkage [kinematic]: the across-dip, or horizontal, linkage of two (usually coeval) faults or other types of fractures that were initially geometrically uncoupled (cf. Mansfield and Cartwright, 1996).

Strike-slip fault [geological and kinematic]: fault in which the displacement is in the horizontal plane, parallel to the strike of the fault (e.g., Biddle and Christie-Blick, 1985).

Stylolite [geological]: surface on which insoluble residues are concentrated as pressure solution removes such soluble minerals as calcite or quartz (e.g., Stockdale, 1926). The teeth of stylolites point in the shortening direction, and, assuming the stylolites initiated as flat planes and did not propagate out of plane, their amplitudes represent a minimum estimate of the amount of shortening (compaction) that has occurred (e.g., Rispoli, 1981). Stylolites have been called antitacks (Fletcher and Pollard, 1981) because contraction occurs across the plane. “Bedding-parallel stylolites” are usually assumed to be formed by the weight of the overburden (e.g., Safaric and Davison, 2005), while “tectonic stylolites” are at a high angle to bedding or sub-horizontal and formed by tectonic stresses (e.g., Letouzey and Trémolières, 1980). Single or multiple sets of stylolites can form stylolite networks (e.g., Ben-Itzhak et al., 2014). Also see slickolite.

Surface, fault or other type of fracture [geometric]: a surface created by brittle failure of rock. Applied to dykes (e.g., Kattenhorn and Watkeys, 1999), faults (e.g., Gephart, 1990), joints (e.g., Pollard and Aydin, 1988), etc.

Swarm, fault or other type of fracture [geometric]: cluster of closely spaced faults or other types of fractures (e.g., Belayneh et al., 2007). Also see corridor, fault or other type of fracture.

Synthetic fault [geometric and kinematic]: originally defined by Cloos (1928) as a minor fault that dips in the same direction as dipping beds. Synthetic fault is now used for a minor fault that has the same shear sense and a similar orientation to a related major fault (e.g., Gibbs, 1984). Also see conjugate.

T, U

Tensile fracture [kinematic and mechanical]: see extensional fracture (e.g., McGrath and Davison, 1995) and mode I. Also called tension fracture.

Tension gash [geological]: see array, fault or other type of fracture.

Tensional fracture [kinematic and mechanical]: see extensional fracture (e.g., McGrath and Davison, 1995) and mode I. Also called tensile fracture. See Pollard and Aydin (1988, p. 1186).

Thrust fault [geological and kinematic]: gently-dipping fault (usually considered to have a dip of less than 30°), in which the hanging-wall (rocks above the fault) are displaced upwards in relation to the footwall (rocks below the fault) (e.g., Willis, 1935). Also see reverse fault.

Tip damage zone [kinematic and mechanical]: area of deformation formed in response to stress concentration at a fault tip (Fig. 5) (Kim et al., 2004); see also process zone.

Tip line [kinematic]: line of zero displacement around the ends of a fracture, e.g., around a fault (e.g., Walsh and Watterson, 1987). Also see tip, fault or other type of fracture.

Tip point, fault or other type of fracture [mechanical]: the point in 2D view at which displacement on a fault or other type of
fracture trace decreases to zero (e.g., Atkinson, 1987; Walsh and Watterson, 1988; Cowie and Shipton, 1998). Also see I node.

Trace length [geometric]: see length.

Trace [geometric]: the line made by a fault or other type of fracture as it intersects the plane of observation (e.g., Bridwell, 1975; Muraoaka and Kamata, 1983).

Trailing (geometric and kinematic): where two new faults or other types of fractures are connected via an older fault or other type of fracture, on which renewed displacement occurs to connect the two later faults or other types of fractures. Trailing faults are illustrated by Nixon et al. (2014) and trailing veins shown by Virgo et al. (2013, Fig. 12c).

Transfer fault [kinematic]: fault that allows kinematic-linkage between two other faults, commonly at a high angle to those faults (e.g., Karson and Rona, 1990).

Transform fault [geological]: defined by Biddle and Christie-Blick as “a strike-slip fault that acts as a lithospheric plate boundary and terminates at both ends against major tectonic features such as oceanic ridges subduction zones or rarely other transform faults that are also plate boundaries”, i.e., it enables geometric- and kinematic-linkage between plate-scale structures.

Triple junction [geological]: where three fracture traces at approximately 120° to each other meet at a point, commonly used for the boundaries of three tectonic plates (e.g., McKenzie and Morgan, 1969). Also see polygonal faults, cooling joints.

V, W

Vein [geological]: defined by the Oxford English Dictionary (1899) as “a deposit of metallic or earthy material having an extended or ramifying course under ground; a seam or lode; spec. a continuous crack or fissure filled with matter (esp. metallic ore) different from the containing rock”. First usage is credited to Trevisa (1387). A wide range of minerals can fill veins, with quartz, calcite and anhydrite being especially common. See Bons et al. (2012) for a review.

Vertex [topological]: the midpoint of a line, e.g., the centre fault or other type of fracture trace (Andresen et al., 2013; Morley and Nixon, 2016). See also edge, equivalent network and vertex degree.

Wall damage zone [kinematic and mechanical]: area of deformation resulting from the propagation of faults through rock (Fig. 5), or from damage associated with the increase in slip on a fault (Kim et al., 2004). See damage zone.

Wing crack [kinematic]: extension fracture developed near the tips of shear fractures (e.g., Wilkins et al., 2001) to accommodate displacement variations along the shear fractures. Also see horsetail and pinnate.

X, Y, Z

X-node [topological]: the intersection point between two crossing faults or other types of fractures, with the traces thereby forming an X pattern (Fig. 2) (Manzocchi, 2002; Sanderson and Nixon, 2015). They are rare in fault networks due to the difficulty in preservation with increased displacements (Nixon et al., 2012). See topology, node, connecting.

Y-node [topological]: where one fault or other type of fracture ends at another fault or other type of fracture, with the traces thereby forming a Y pattern (Fig. 2). Such a geometric relationship can be produced in a number of ways including spalling, abutting and cross-cutting relationships (Manzocchi, 2002; Sanderson and Nixon, 2015). See topology, node, connecting node.

Zone, fault or other type of fracture [geometric]: a system of related fracture segments that interact and link, and are restricted to a relatively narrow band or volume (e.g., Nevin, 1931). Childs et al. (2009) define fault zone thickness as “the distance between synthetic slip-surfaces (same dip direction and sense of offset) that can be demonstrated at outcrop to be kinematically related and which each accommodate at least a few percent of the total offset”.

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