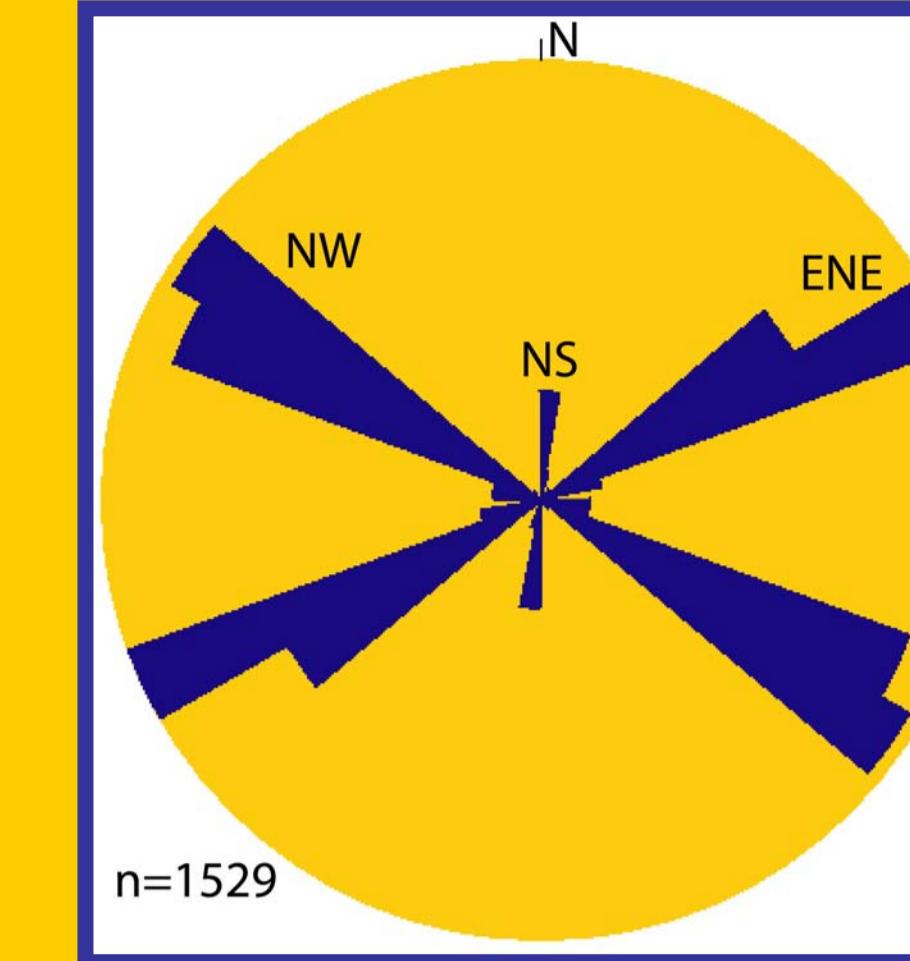


The documented relationship of NW and ENE joint density and TOC content of the Rhinestreet shale has been observed in the Dunkirk shale along the Lake Erie shoreline, as well as in the Genesee shale of the Finger Lakes district (Lash et al., 2004). NS-trending joints, however, are confined to a narrow stratigraphic interval at the contact of the Rhinestreet shale and underlying Cashaqua shale as well at the contacts of gray shale intervals and overlying black shale within the Rhinestreet shale. The preferential NS jointing of gray shale at its contact with overlying black shale has been described at the contact of the West River shale and overlying Middlesex black shale and the Hanover gray shale and overlying organic-rich Dunkirk shale (Lash, in press). All observed abutting relations indicate that the NS joints are the older structures, followed chronologically by the NW trending joints and finally the ENE joints. The orientation of the NW-trending joints is consistent with their propagation in an Alleghanian remote stress field (e.g., Engelder and Geiser, 1980).

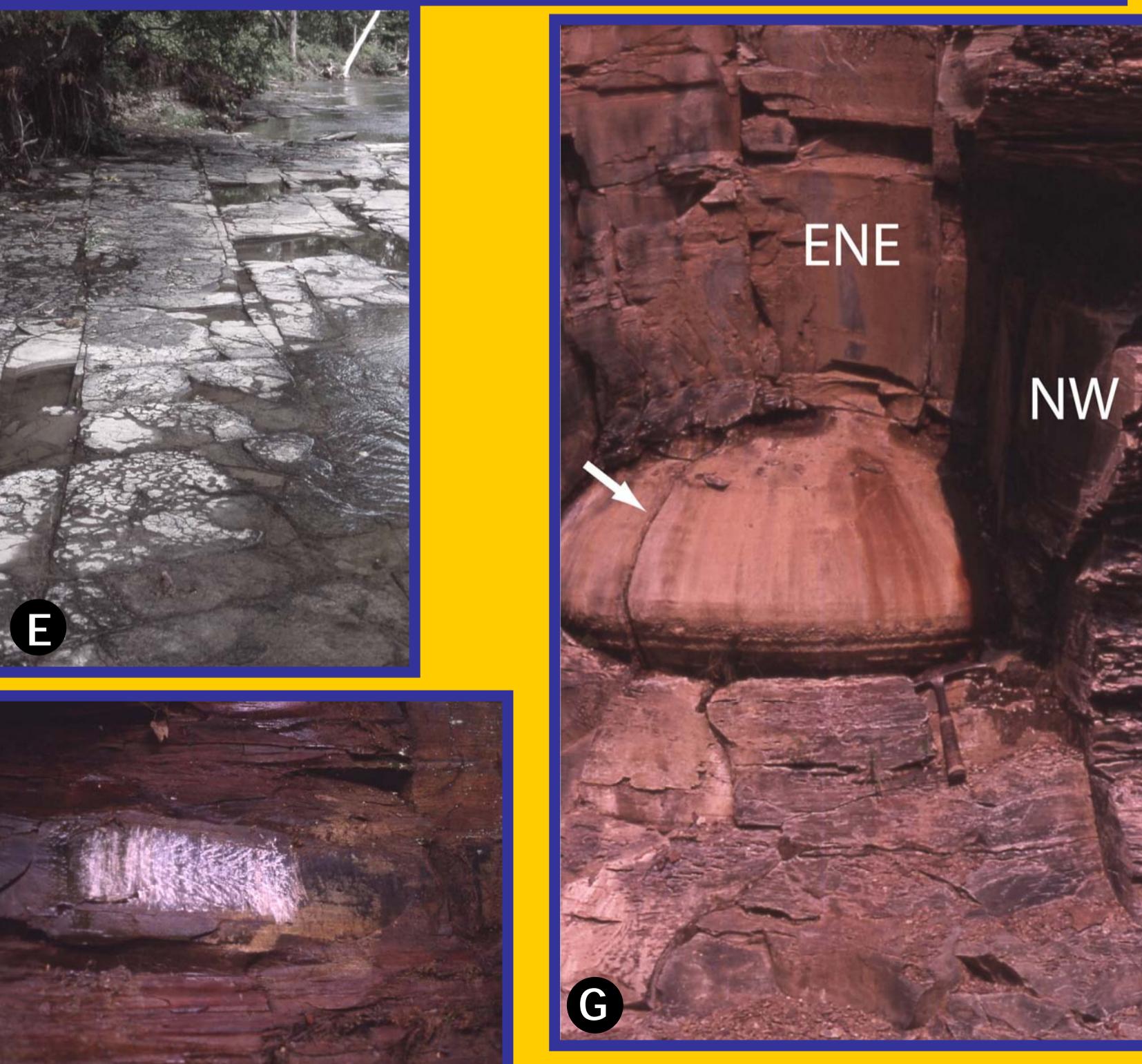
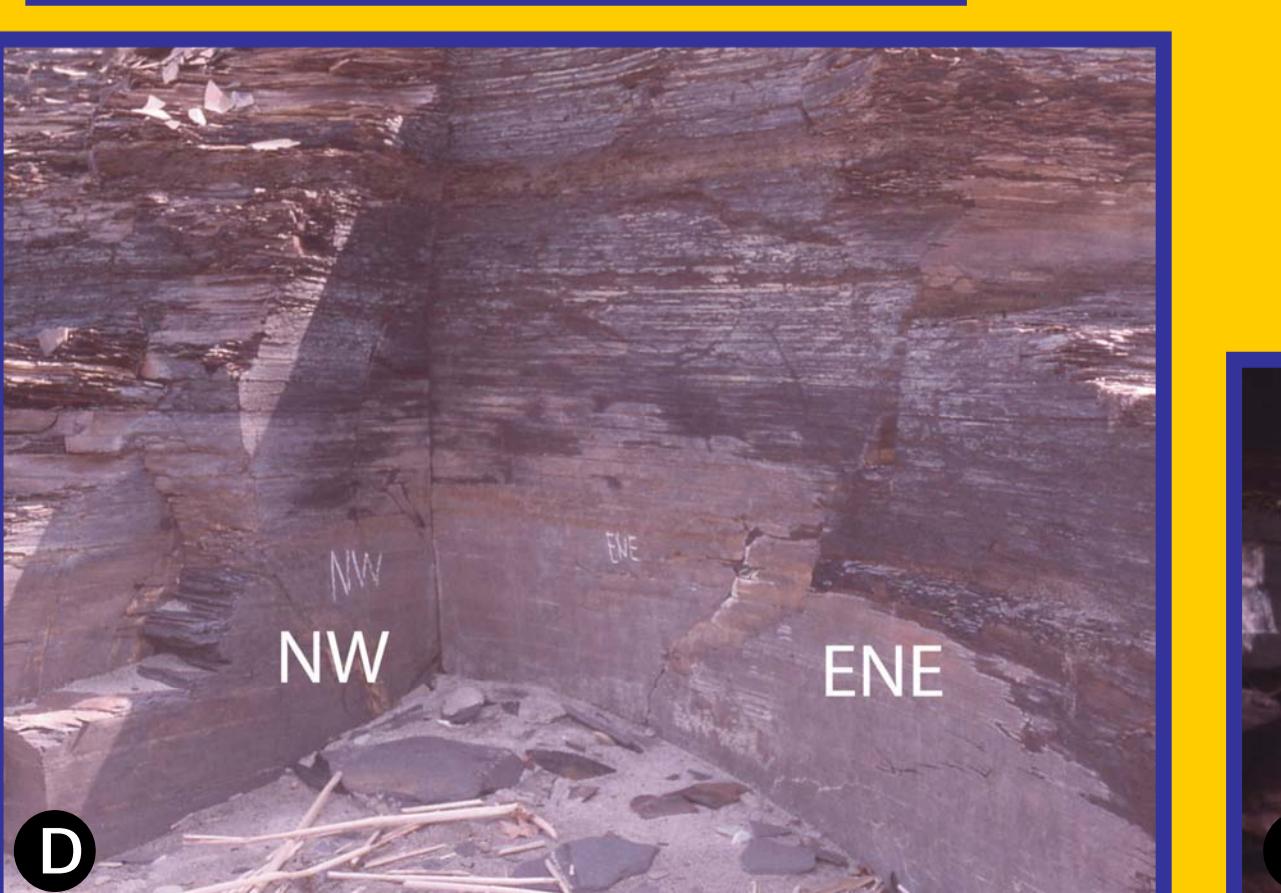
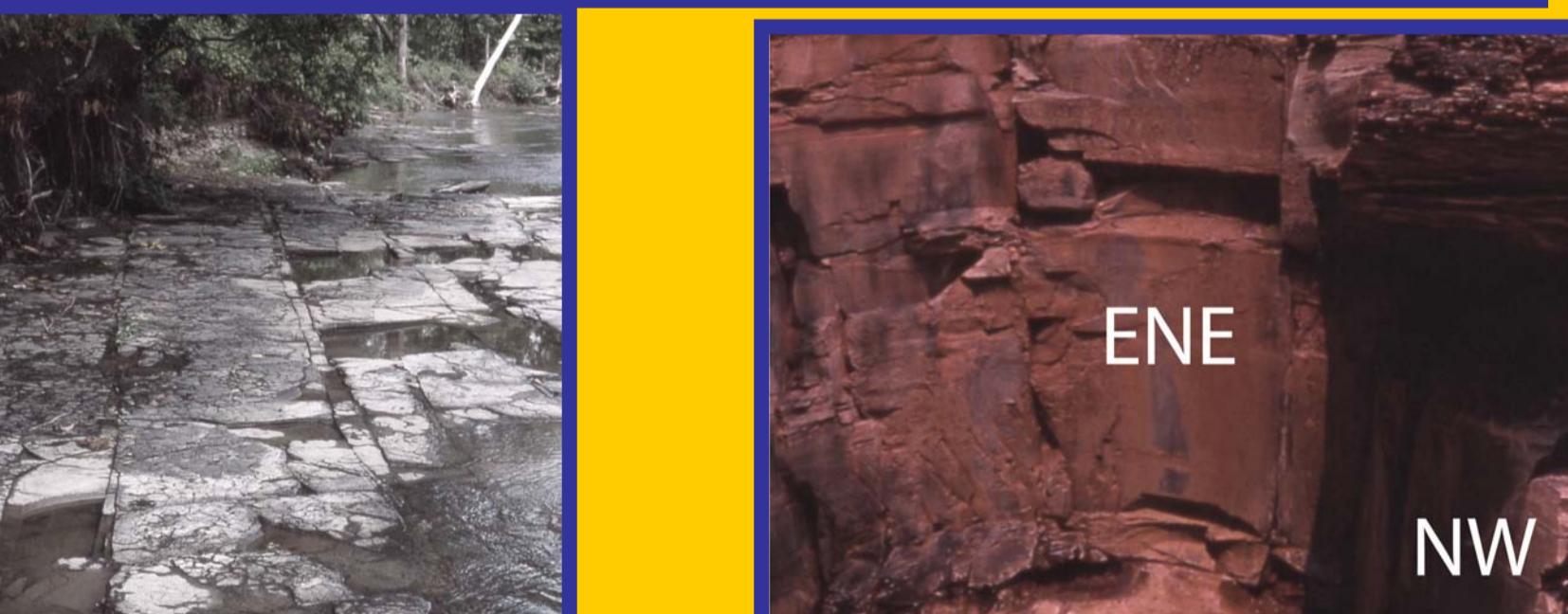
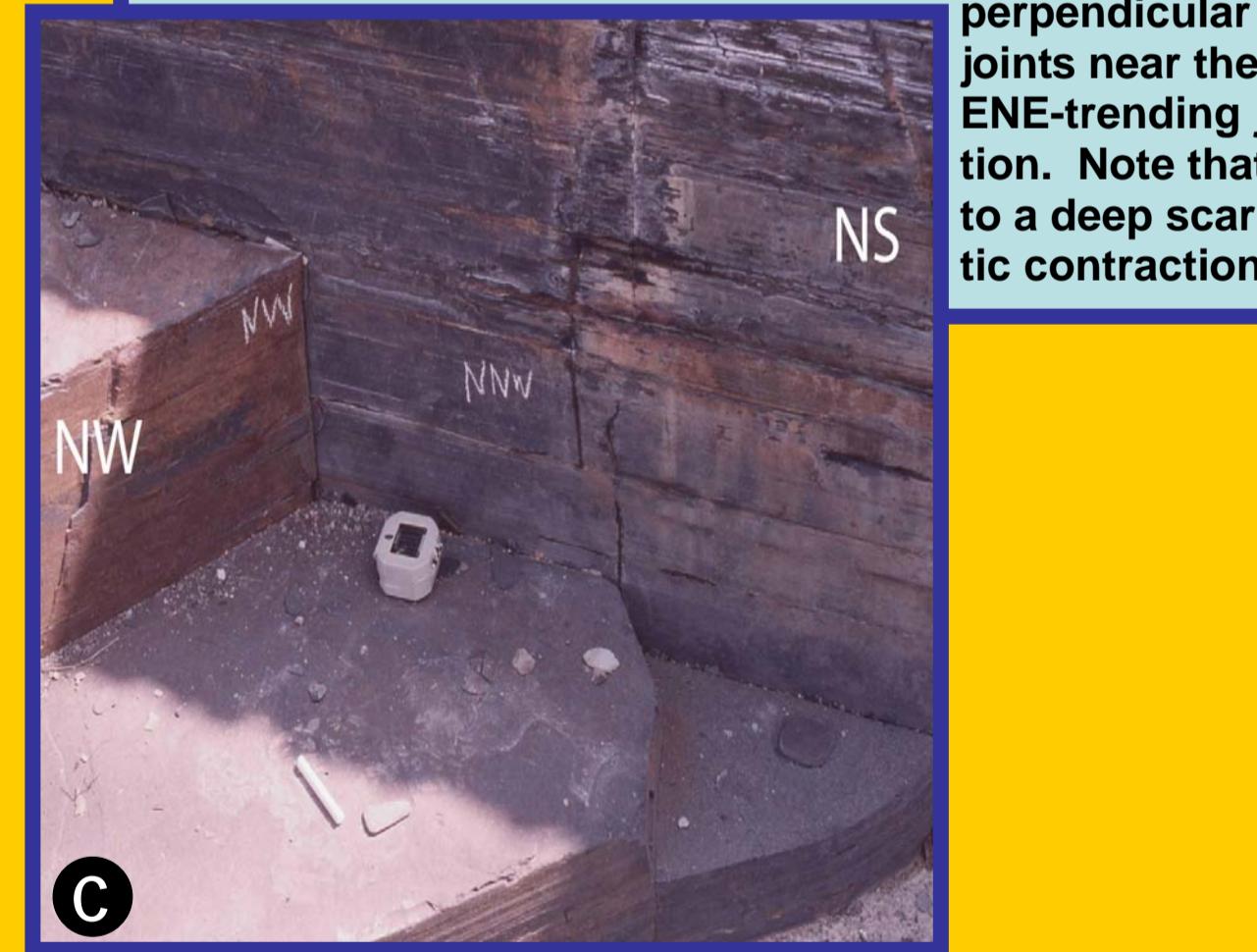
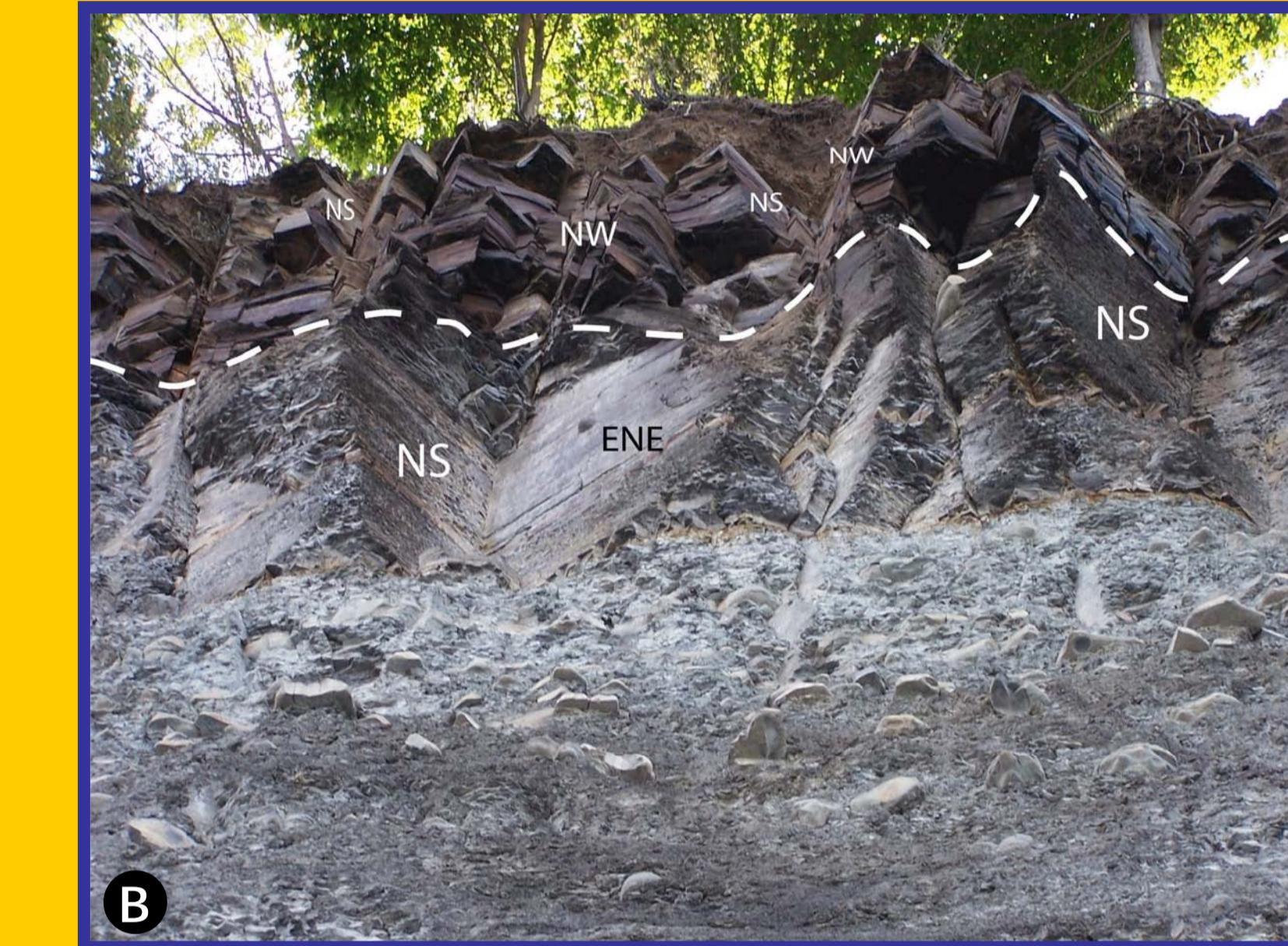
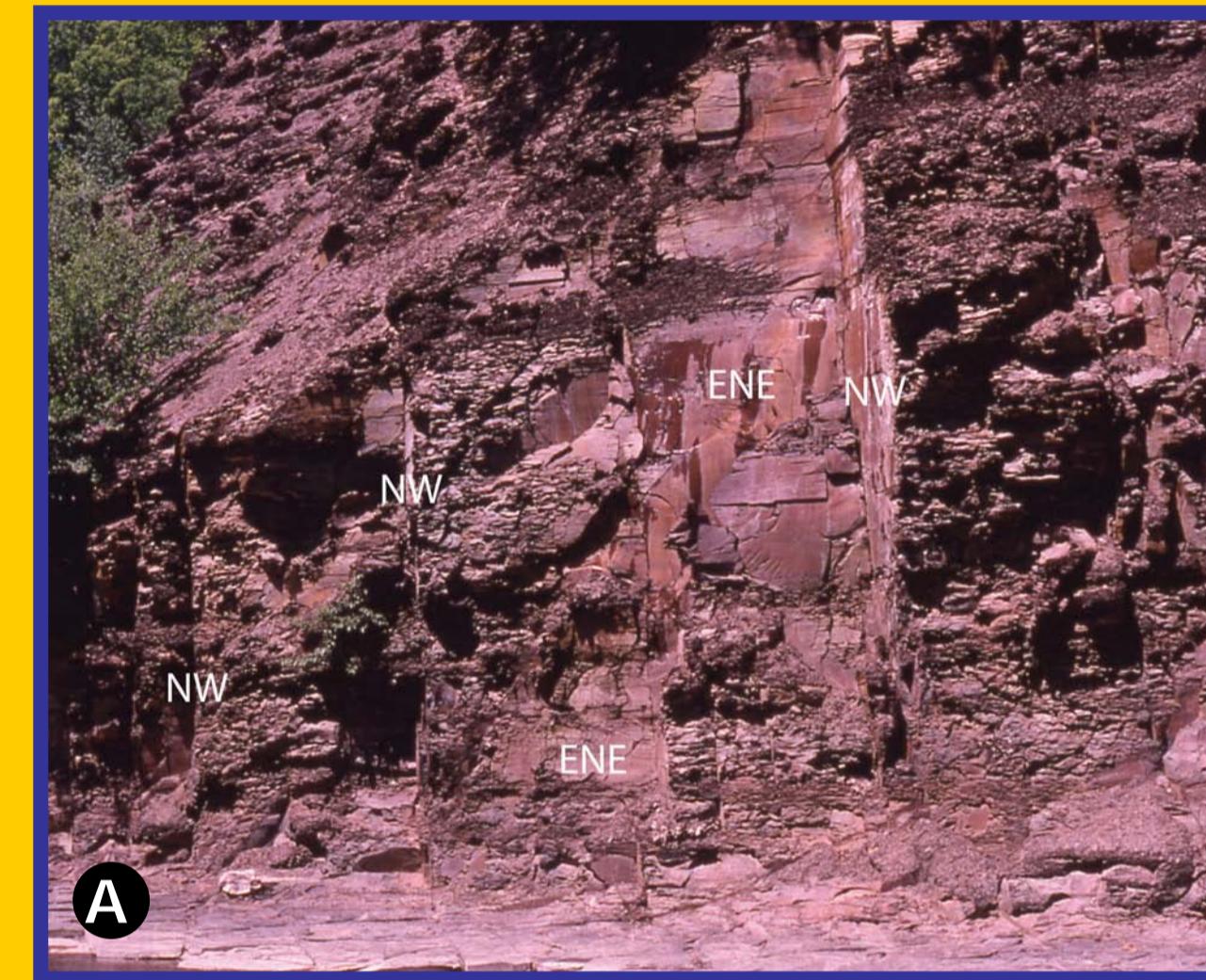
Studied joints of all sets are essentially vertical, very planar and continuous, commonly extending beyond the limits of exposure. No joints show any evidence of slip, an observation that contrasts with reactivated joints described from deeper within the Catskill Delta complex (e.g., Engelder et al., 2001). Although the shales typically lack surface ornamentation, largely a consequence of the rock being so fine grained that the rupture path is not disrupted by small-scale heterogeneities, we have observed plumose structure on a number of joints surfaces, especially after being chalked, indicating that the joints are open mode (mode I) cracks.

Like other vertical joints carried by rocks of the Catskill Delta complex in New York State (e.g., Engelder and Oertel, 1985; Lacazette and Engelder, 1992; McConaughy and Engelder, 1999), ENE- and NW-trending joints observed in the Cashaqua-Rhinestreet-Angola sequence are interpreted to be fluid-driven joints, specifically natural hydraulic fractures (NHF; Lash et al., 2004; Lash and Engelder, 2005; Lash, in press). Evidence for such an interpretation includes the locally large height:spacing ratio of the joints, quite at odds with their formation as tensile fractures produced by joint-normal loading or stretching (e.g., Ladeira and Price, 1981; Engelder and Fischer, 1996) and the fact that most of these joints terminate at their contacts with carbonate concretions. NS-trending joints, the oldest set carried by these rocks, appear to have formed as a result of tensile stress perhaps aided by pore fluid pressure as evidenced by joints that penetrate and locally cross-cut carbonate concretions (e.g., McConaughy and Engelder, 1999).



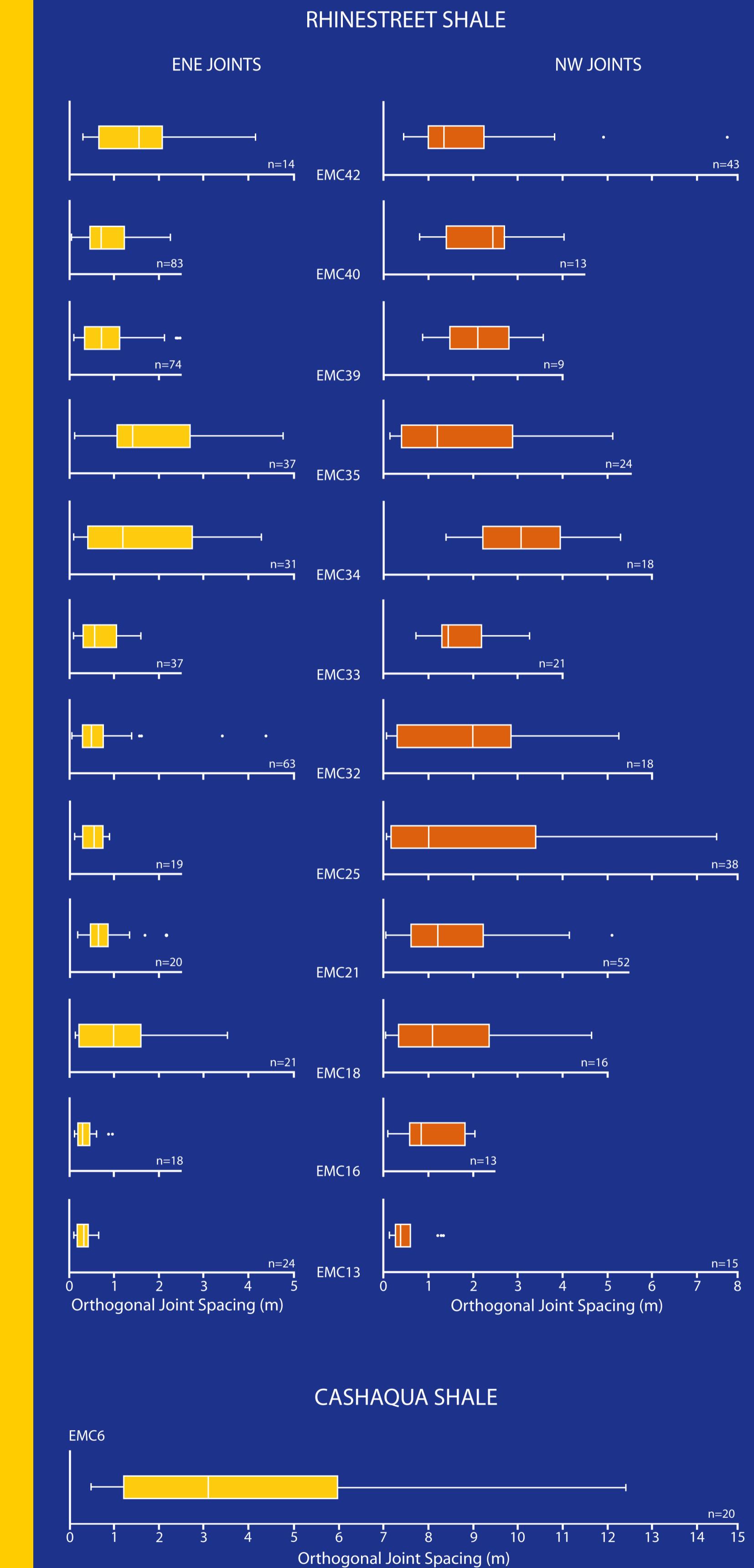
JOINTS

Three regional joint sets are carried by the Cashaqua-Rhinestreet-Angola sequence in the area of study; NS (~352°), NW (~310°), and ENE (~072°). Joints of the latter two sets are present throughout the entire sequence on Eighteenmile Creek though they are most densely formed (i.e., most closely spaced) in the lower, organic-rich, interval of the Rhinestreet shale.



(A) Heavily jointed Rhinestreet shale showing ENE (parallel to image)- and NW (perpendicular to photograph)-trending joints; (B) NS-trending joints at the top of the Cashaqua shale (contact of Cashaqua and Rhinestreet shale indicated by the white dashed line). Note the heavily fractured nature of the basal Rhinestreet shale; (C) Abutting relation of NW and NS (older) joints; (D) Curving-perpendicular abutting relation of ENE and NW (older) joints; (E) Close-spaced NW-trending joints near the bottom of the Rhinestreet shale; (F) plumose hackle on chalked surface of an ENE-trending joint; (G) Field relations of NW and ENE joints and a large carbonate concretion. Note that neither joint shows any deviation around the concretion. White arrow points to a deep scar on the concretion created by a NS-trending joint, evidence for loading by elastic contraction as opposed to fluid decompression.

JOINT SPACING



Box-and-whisker diagrams representing orthogonal joint spacing distribution for ENE and NW joints of the Rhinestreet and Cashaqua shales (refer to detailed lithologic log for stratigraphic locations of scanlines). The box encloses the interquartile range of the data set population; the interquartile range is bounded on the left by the 25th percentile (lower quartile) and on the right by the 75th percentile (upper quartile). The vertical line drawn through the box defines the median value of the data population, and the "whiskers" define the extremes of the sample range. Statistical outliers are represented by data points that fall outside the extremes of the sample range.

Note that the Cashaqua shale at its contact with the Rhinestreet shale carries only ENE-trending joints.