Bed-Parallel Expansion Seams and Shear Surfaces in Shales*

W. Jamison[1]

Search and Discovery Article #51053 (2014)
Posted December 29, 2014

*Adapted from extended abstract prepared in conjunction with presentation at CSPG/CSEG/CWLS GeoConvention 2013, (Integration: Geoscience engineering Partnership) Calgary TELUS Convention Centre & ERCB Core Research Centre, Calgary, AB, Canada, 6-12 May 2013, AAPG/CSPG©2014

[1] Shell Canada & The Upper Crust Inc., Calgary, AB, Canada (wjamison@shaw.ca)

Abstract

Bed-parallel expansion seams, a.k.a. "beef", are common in many organic-rich shales. They have been recognized in shales since the mid-19th century, and the origin of these features has been contemplated for almost a century. They have been the subject of renewed interest with the current interest in shales as a reservoir rock for gas and liquid hydrocarbons. Recent studies suggest these features formed in response to extreme overpressures that developed when kerogens were converted to hydrocarbons. The preferential development of expansion seams over vertical fractures can be explained using a model of uniaxial strain.

Bed-parallel shear zones or slip surfaces are also common in some shales. These shear features have a morphology different and distinct from expansion seams, but the two fabrics are commonly observed to be intercalated. These shear features are inferred to have formed in tectonic settings and/or structural positions where bed-parallel shear occurred within the time of catagenesis. The bed-parallel shear features commonly contain surfaces that have little or no cohesion, and they could create impediments to the vertical propagation of hydraulic fractures.

Introduction

Bed-parallel expansion seams occur in as an interwoven system of short, lenticular cracks (Figure 1). These features are common in many shales and they have been described in the literature since the mid-19th century (Sorby (1860), initially referred to as "beef-in-shales." These features are usually visible to the naked eye only when they are infilled with mineral cements (most commonly calcite), but they can also occur with bitumen infill, a combination of bitumen and mineral cements, or no infill. The mineral cements usually form a fibrous texture, with the crystals elongate perpendicular to bedding (e.g. Taber, 1918). Several studies have assessed their genesis from the isotopic signature of the cements (e.g. Marshall, 1982; Riediger and Cognigli, 1992), but there has been an inconsistent interpretation of their depth of formation, ranging from a few 10's of metres to several km's. Recent studies (e.g. Rodrigues et al., 2009) of these features commonly attribute their formation to fluid overpressures developed in ultra-low permeability source rocks during the time their kerogens are converted to hydrocarbons (catagenesis), thus indicating they have formed at considerable depth. Stable isotope analysis of cements within expansion seams and vertical fractures formed in the same rock units provides evidence that both the vertical and horizontal features formed at roughly the same time. These are, in fact, competing deformational processes. The preferential development of expansion seams vs. vertical fractures depends on the evolution of the stress state within the rock during the catagenetic overpressuring, as explained below.

Stress Conditions for Expansion Seam Development

Bed-parallel expansion seams are observed in shales in a variety of settings, including regions where Sv was probably Smax at the time of the formation of these features. The common model to describe the change in effective stress that occurs during pore pressure increase suggests the Mohr circle will shift to the left until it intersects the failure envelope (Figure 2). In a setting where Sv = Smax, it is expected that the rock would fail by the development of vertical fractures rather than horizontal opening.

However, at depth within a basin, the bounding rocks restrict the lateral expansion of the rock, which results in a condition referred to as uniaxial *strain* (Figure 2). In this situation, the effective horizontal stress will be less severely impacted by an increase in the pore pressure than the vertical stress (Figure 3). This can result in a change in the relative magnitudes of the principal stresses and the size of the Mohr circles as the pore pressure increases (Figure 3). Even within an extensional basin, it is possible to increase the pore pressure to overburden pressure (and create expansion seams) before the rock fails by vertical fracturing. The controlling factors are Sv, Shmin and Poisson’s ratio.

Bed-Parallel Slip Surfaces and Shear Zones

Bed-parallel slip surfaces and shear zones (Figure 4) are observed in many shales that are within or marginal to contractional tectonic settings (such as fold-and-thrust belts or transpressional systems). Indications of shear movement commonly occur in the form of slickensides on parting surfaces or a shear fabric in the bounding rock and cements. These shear zones have a different morphology and a different sense of movement than the expansion seams. However, the bed-parallel shear zones are commonly observed to be intercalated with bed-parallel expansion seams, suggesting a probable genetic link between these two features. The bed-parallel shear zones are expected, and observed, to form in regions and/structural positions where bed-parallel shear stresses would probably have developed at some time during the phase(s) of catagenesis. Strata-bound overpressures due to catagenesis give fresh support to the concepts of Hubbert and Rubey (1959).

There is usually at least one surface within the shear zone that is parted or has very weak cohesion relative to the host rock. Therefore, these bed-parallel shear zones may create a significant impediment or barrier to the vertical propagation of a hydraulic fracture.

Conclusions

- Bed-parallel expansion seams are openings in the rock that occur in association with localized extreme overpressure conditions that develop at the time of HC generation (catagenesis).
- Bed-parallel expansion seams are a competing mechanism with vertical fractures. This competition depends on the relative magnitude of Sv and Shmin at failure.
- Bed-parallel shear zones can develop in association with the expansion seams if there co-exists tectonic stresses of the right orientation.

- Bed-parallel expansion seams and shear zones are most evident where they are infilled with mineral cements.
- Localized, strata-bound overpressured zones associated with catagenesis could be important for the development of major detachment zones in fold-and-thrust systems (Hubbert-Rubey model).
- Surfaces of non-cohesion associated with bed-parallel slip zones could be impediments to vertical HF propagation.

References Cited

Hubbert, M.K., and W.W. Rubey, 1959, Role of fluid pressure in mechanics of overthrust faulting: I. Mechanics of fluid filled porous solids and its application to overthrust faulting: Geological Society of America Bulletin, v. 70, p. 115-166.

Marshall, J.D., 1982, Isotopic composition of displacive fibrous calcite veins; reversal in pore-water composition trends during burial diagenesis: Journal of Sedimentary Petrology, v. 52, p. 615–630.

Riediger, C.L., and M. Conigli, 1992, Early diagenetic calcites and associated bitumens in “Nordegg Member”: implications for Jurassic paleogeography of the western Canada Sedimentary Basin: Bulletin of Canadian Petroleum Geology, v. 40, p. 381-394.

Rodrigues, N., P.R. Cobbold, H. Loseth, and G. Ruffet, 2009, Widespread bedding-parallel veins of fibrous calcite (‘beef’) in a mature source rock (Vaca Meurta Fm., Neuquen Basin, Argentina): evidence for overpressure and horizontal compression: Journal of the Geological Society of London, v. 166, p. 695-709.

Sorby, H.C., 1860, On the origin of ‘cone-in-cone’: British Association for the Advancement of Science, Report of the 29th Meeting, 1859. Transactions of Sections, Geology, 124 p.

Taber, S., 1918, The origin of veinlets in the Silurian and Devonian strata of New York: Journal of Geology, v. 26, p. 56–63.

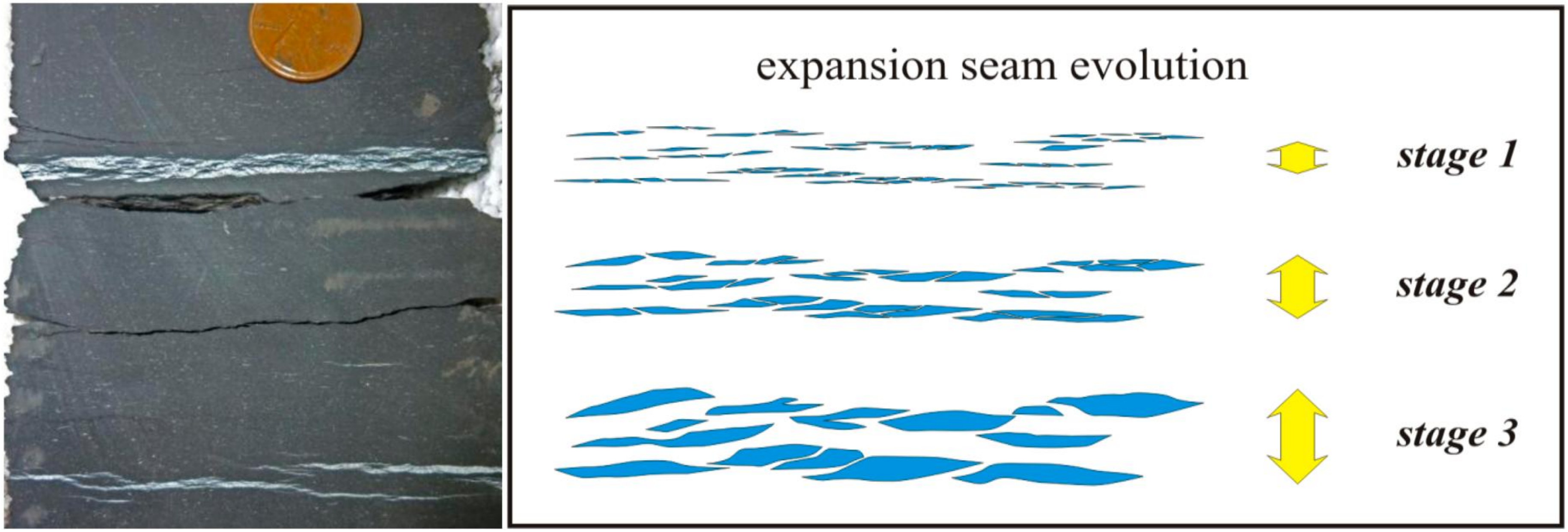
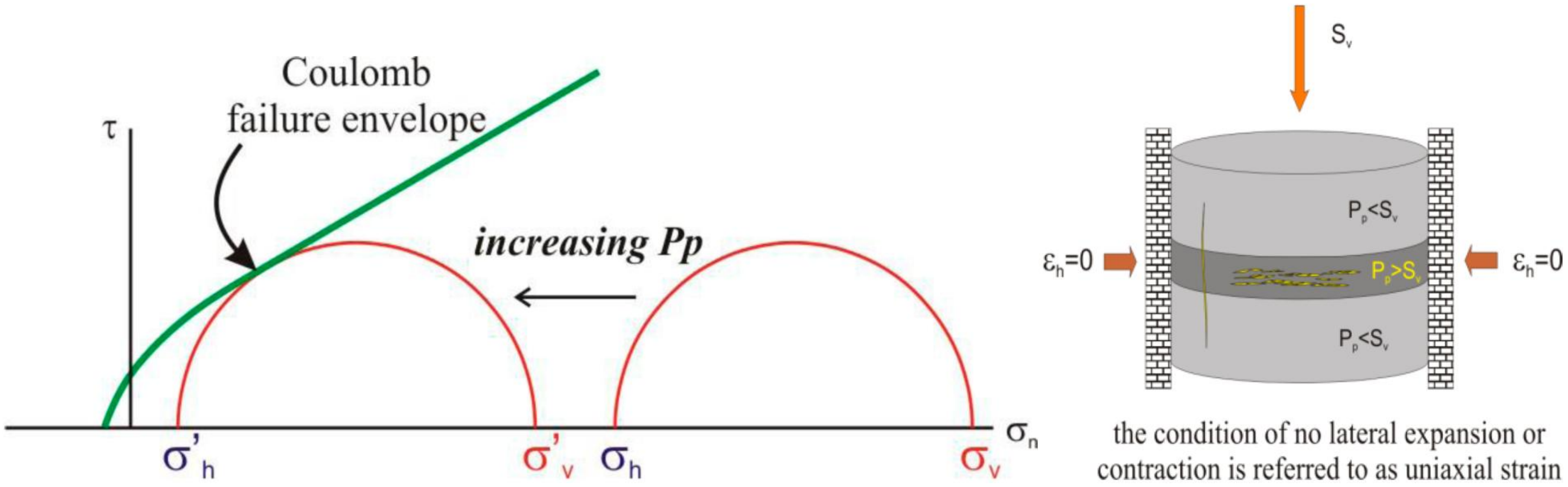


Figure 1. Left, bed-parallel expansion seams, or “beef,” in core from the Haynesville Fm. Right, diagram to illustrate the evolution of expansion seams.



the condition of no lateral expansion or contraction is referred to as uniaxial strain

Figure 2. Left, Mohr stress diagram illustrating the change in stress commonly associated with an increase in pore pressure. Right, diagram to illustrate the condition of uniaxial strain.

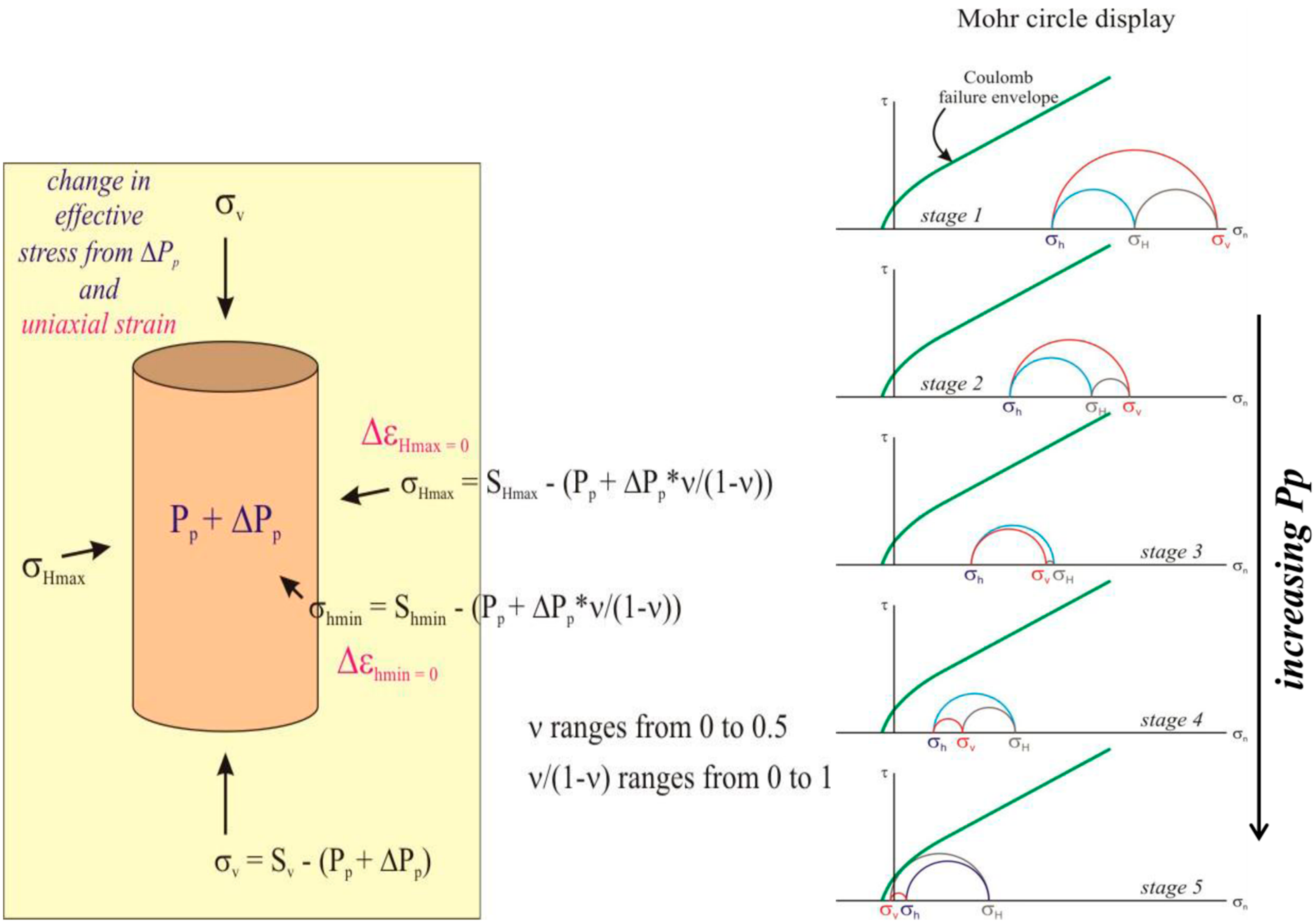


Figure 3. Left, under the condition of uniaxial strain, an increase in the pore pressure will change the horizontal effective stresses less than the vertical stress. Right, the relative magnitudes of the principal stresses and the size of the Mohr circles can change as pore pressure increases under uniaxial strain conditions.

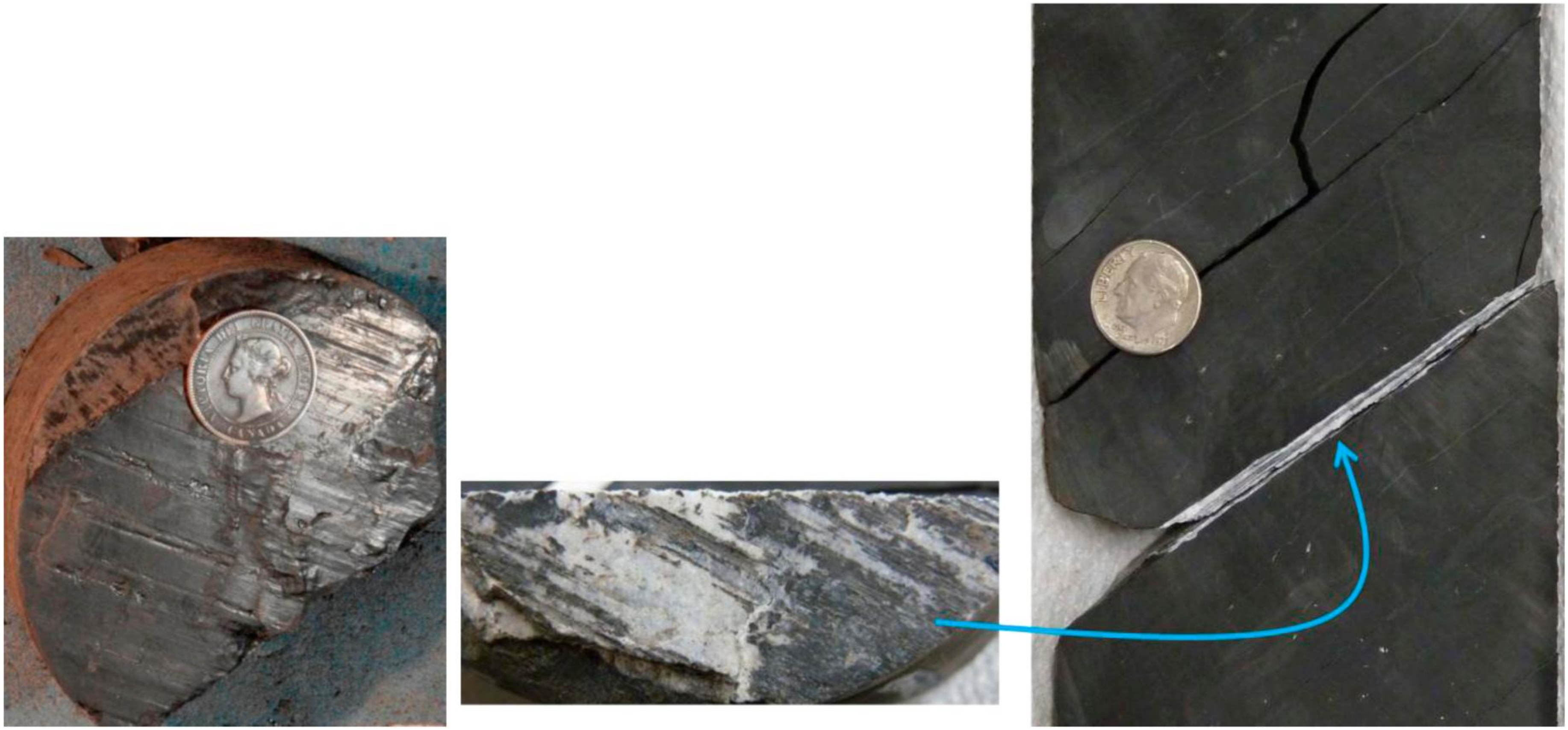


Figure 4. Left, bedding-parallel slip surface in Second White Specks Fm. in Foothills margin region. Right, calcite-lined shear zone and slip surface in dipping beds on flank of large detachment zone, Longmaxi Fm.