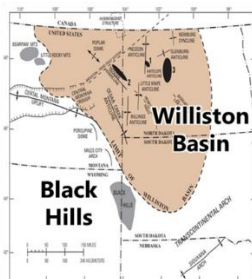


Field Workshop: Inyan Kara Group, Lower Cretaceous, Black Hills (SD, WY)

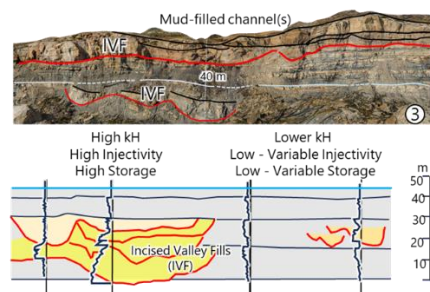
Outcrop Studies for Williston Basin Resource Management and Reservoir Analogs



Source: wikipedia.org/wiki/Williston_Basin



Source: Google Earth, Landsat Image, Copernicus



Beaubouef (2025)

October 12-17, 2025
Hot Springs – Deadwood, South Dakota
Registration @ [Inyan Kara Field Workshop](#)

Preliminary itinerary for

**Inyan Kara Group, Lower Cretaceous, Black Hills,
South Dakota & Wyoming**

October 12-17, 2025

Hot Springs – Deadwood, South Dakota

Executive Summary

In the Williston Basin, North Dakota, the Inyan Kara Formation (early Cretaceous) is the primary subsurface injection zone for produced water. It is comprised of extensive sandstone aquifers overlain by widespread shales of the Skull Creek Formation, resulting in large potential for saltwater disposal (SWD). It is also considered a potential geologic sequestration unit for carbon capture and storage (CCS). This subsurface aquifer is equivalent to the Lakota and Fall River Formations (Inyan Kara Group) that outcrop in the Black Hills of South Dakota and Wyoming (Fig 1). Both in the subsurface and outcrops, the Inyan Kara strata are predominantly non-marine to marginal marine. They contain incised valley-fills (IVFs), multiple depositional sequences, and reflect regressive to transgressive depositional cycles within an overall (longer-term) transgressive stacking pattern. As a result, the Inyan Kara interval exhibits a distinctive, twofold stratigraphic subdivision. While the lower sequences of the Lakota Formation exhibit mainly non-marine depositional environments, the upper sequences of the Fall River Formation reflect more shallow marine influences. Despite this predictable, two-fold stratigraphy, the Inyan Kara strata are extremely heterogeneous over short distances.

The Black Hills outcrops provide an important analog for the types of stratigraphic and sedimentologic relationships expected within the Inyan Kara sequences in the subsurface of the Williston Basin. Identified IVFs are compound, or composite in nature, consisting of ~3-10 km wide, generally northwest trending, stacked channel systems, containing a variety of thickly bedded sandstone types, encased in finer-grained, more thinly bedded lithofacies. Based on outcrop studies, key uncertainties impacting produced water (SWD) or CO₂ disposal (CCS) trends in the Inyan Kara aquifer are the; a) paleogeographic/environmental setting within the basin, b) distribution of IVFs, and c) their internal architecture, and constituent lithofacies. Four regions of the Black Hills outcrop study area have been chosen for this field workshop (fig 2). The workshop itinerary has been constructed to allow participants to examine the heterogeneity of the Inyan Kara Group from proximal to more distal settings, along an approximately 160 km long, SE-NW transect. Beyond the specific benefits to Williston Basin activities, the outcrops provide a window into the broader geological history of the Western Interior Seaway, showcase a diverse range of sedimentary environments and deposits, and provide important insights for analogous systems in other basins and settings. An extensive library of drone-based, 3D photogrammetry images (earth models) of the outcrops is available (Fig 3).

Field Workshop Itinerary

- ➔ Arrive Rapid City Regional Airport, Sunday pm. Meet group, and drive to Hot Springs. Workshop safety briefing and introduction to the geology of the Inyan Kara, Black Hills.
- ➔ Participants with Inyan Kara (or relevant) experience are invited to bring materials that can be shared during the workshop.

Day 1 (Monday), from Hot Springs to Maverick Junction, Fall River County, South Dakota

Objectives: observe the a) Inyan Kara Group in a thick, proximal paleo-environment location with high net:gross sandstone content, b) stratigraphic subdivisions and stacking patterns (sequences, systems tracts vs. formations and members), c) margin-axis relationships of a compound incised valley-fill, and c) the “bottom-loaded” cycles of valley fill.

Implications: SWD, CCS completions targets are plentiful, injectivity and storage potential are very high.

1. Stop 1.1. (optional) lateral accretion packages, fluvial channel-fills, Lakota Formation, Chilson member (Klcss2) at Fall River roadcut
2. Stop 1.2. (optional) lateral accretion packages, fluvial channel-fills, Lakota Formation, Chilson member (Klcss2) at Dudley Canyon
3. Stop 1.3. lateral accretion packages, fluvial channel-fills, with intervening flood plain mudstones, Lakota Formation, Chilson member (Klcss2) at Slaughter Canyon; the reference section for Lakota Formation.
4. Stop 1.4. fluvial, coastal plain and marine deposits of the Fall River Formation at Scenic Road-Fall River Roadcut (Kfmss5 - Kfuss6); the type section of Fall River Formation.
5. Stop 1.5. View of north trending, compound incised valley-fill containing Lakota and Fall River Formations contained in east dipping hogback at Buffalo Gap area
6. Stop 1.6. (optional) Fall River - Lakota contact (sequence boundary), incised valley-fill margin, at Fuson Canyon; the type section for Fuson member of Lakota Formation.

Day 2 (Tuesday), from Hot Springs to Red Canyon Road area, Fall River County, South Dakota

Objectives: observe the a) Inyan Kara Group in a medial-proximal paleo-environment location with moderate thickness and net:gross sandstone content, b) the stratigraphy of WNW trending compound incised valley fill, c) lateral depositional environment/lithofacies facies changes that have occurred within the Fall River Formation and d) margin-to-axis relationships of within the upper, Fall River Formation portion of the compound valley-fill.

Implications: SWD, CCS completions targets are plentiful, injectivity and storage potential are high, but permeability structure in upper portion (Fall River Formation) is environment (lithofacies) dependent. Valley margin and (especially) interfluvial positions are low KH

(permeability thickness) locations. Late-stage, mud-filled channels can dissect valley-fill and interrupt reservoir continuity in the Fall River sequences.

1. Stop 2.1. Sundance and Morrison formations
2. Stop 2.2 Debris flow deposits and fluvial channel complexes of the Lakota Formation (Chilson member; Klcs1)
3. Stop 2.3 Fluvial channel complexes of the Lakota Formation (Chilson member; Klcs1)
4. Stop 2.4 Fall River - Lakota contact (sequence boundary) focusing on the western exposure of the axial portion of the Fall River compound valley fill (Kfms5)
5. Stop 2.5. Southern, marginal portion of Fall River compound incised valley fill (Kfms5)
6. Stop 2.6. Fluvial sandstones of the underlying Chilson member of the Lakota Formation (Klcs2) with exceptional views of the 3D geometry of stacked fluvial bars
7. Stop 2.7. Shallow marine, tidal flat deposits outside, but adjacent to the Fall River incised valley
8. Stop 2.8. (Optional) The southernmost exposures of upper Fall River Formation containing shallow marine (tidal flats) deposits, punctuated by periods of subaerial exposure, marked by paleosols
9. Stop 2.9. Fluvial to estuarine deposits in the eastern exposures of the axial portions of Fall River compound valley fill (Kfms5) located in a side canyon on the eastern side of Red Canyon

➔ Drive to Deadwood, South Dakota

Day 3 (Wednesday), from Deadwood Oil Creek Road area, Weston County, Wyoming

Objectives: observe a) Inyan Kara Group in a medial-distal paleo-environment location, b) incised valley-fill of the Lakota Formation c) the progressive, stratigraphic transition to progressively marine-dominated (back-stepping) environments in the Fall River Formation.

Implications: SWD, CCS completions targets remain high in the Lakota Formation, but are reduced for the Fall River Formation, and restricted to the lower half. Consequently, injectivity and storage potential are moderate-high, overall. Late-stage, mud-filled channels dissect valley-fill and interrupt reservoir continuity in the Lakota sequences.

1. Stop 3.1. fluvial incised valley fills, with intervening shallow marine parasequences, Lakota Formation (Klcss2, 3)
2. Stop 3.2. (optional) Axis-margin relationships along western margin of fluvial channel complex, Lakota Formation (Klcss3)
3. Stop 3.3. (optional) Fluvial channel complex fill, Lakota Formation, Blacktail Canon
4. Stop 3.4. Fall River – Lakota, sand-on-sand erosional contact (sequence boundary)
5. Stop 3.5. Fall River – Lakota, sand-on-mudstone erosional contact (sequence boundary)

6. Stop 3.6. Fall River marginal marine sandstone (Kfmss5) with distributary channel architectures, and axial to marginal facies changes (possible Keyhole sandstone equivalent)
7. Stop 3.7. Upper, backstepping shallow marine parasequences of the Fall River Formation

Day 4 (Thursday), from Deadwood to Keyhole Reservoir and Government Canyon locations, Crook County, Wyoming

Keyhole Reservoir

Objectives: observe the a) Inyan Kara Group in a distal – medial paleo-environment location, b) coarse-grained, multi-story fluvial channel-fills of the Lakota Formation c) further lateral changes in environment of deposition and lithofacies of the Fall River Formation.

Implications: SWD, CCS completions targets remain high in the Lakota Formation, but are reduced for the Fall River Formation, restricted to the lower half. Overall, injectivity and storage potential are moderate, and highly dependent on the presence (or absence) of the Lakota Formation in this region of the basin.

1. Stop 4.1. Coarse-grained fluvial channel fills, Lakota Formation at the Belle Fourche River, north of Keyhole dam
2. Stop 4.2. Marginal marine, wave dominated, shoreface deposits, Keyhole Sandstone (Type locality), lower Fall River Formation (Kmss5?), north of Keyhole dam
3. Stop 4.3. (optional) Shallow marine, thin-bedded sandstones and mudstones, and overlying Keyhole sandstone, east of dam

Government Canyon

Objectives: observe the a) the Inyan Kara Group in a thin, distal paleo-environment location with low net:grss sandstone content, b) Lakota Formation is comprised entirely mudstone (compared to the nearby Carlile Junction and Keyhole Reservoir areas), highlighting Lakota variability in this portion of the basin, c) further lateral changes in environments of deposition and lithofacies of the Fall River Formation, and, in particular d) the thin bedded, heterolithic nature of most of the Fall River Formation through this region of the basin

Implications: SWD, CCS completions targets are low, and dependent upon the presence (or absence) of fluvial deposits of the Lakota Formation. The Fall River Formation is comprised of thin bedded, fine grained (low permeability) lithofacies. Overall, injectivity and storage potential are poor.

1. Stop 4.4. Multicolored, non-marine mudstones and coal of the Lakota Formation

2. Stop 4.5. Fall River-Lakota contact (sequence boundary) between the uppermost coal of Lakota Formation, and coaly, rip-up clast sandstone of the basal Fall River Formation
3. Stop 4.6. Repeated packages of mudstones and thin bedded sandstone of shallow marine-bay-paludal environments, overlain and incised by medium-coarse grained fluvial sandstone

Day 5 (Friday, 1/2 day), in Deadwood. Wrap-up, review and discussion of Inyan Kara Group, Black Hills

1. Summary of observations, interpretations and implications for Williston Basin
2. General applicability for Exploration and Production
3. Next steps
 - ➔ Depart for Rapid City Regional Airport, Friday pm

Trip overview

Trip at a Glance						
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
LOCATION	12-Oct	13-Oct	14-Oct	15-Oct	16-Oct	17-Oct
Rapid City	Arrive					
Hot Springs				check out		
Deadwood			check in			
Rapid City						Depart

Location

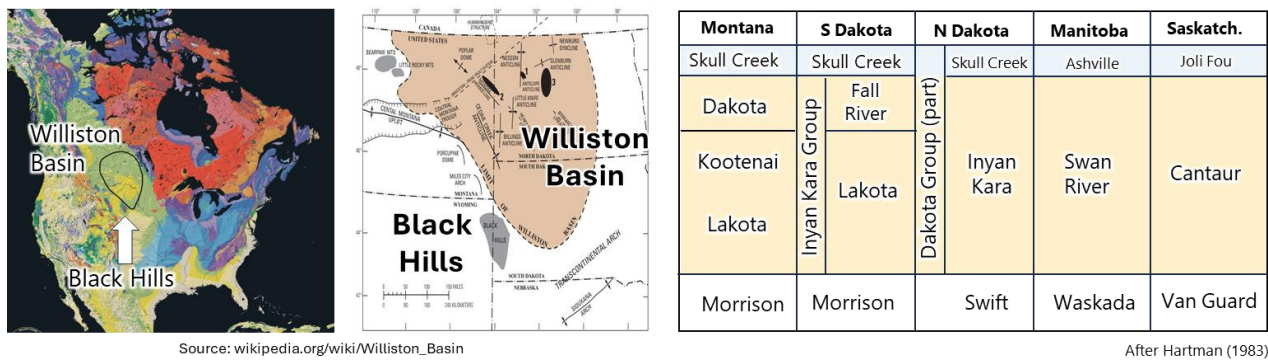


Figure 1. General location maps and Inyan Kara stratigraphic correlation chart. The Inyan Kara formation in the subsurface of the Williston Basin is equivalent to the Lakota and Fall River Formations (Inyan Kara Group) in the Black Hills of South Dakota and Wyoming. Despite differences in tectonic and diagenetic histories and stratigraphic nomenclature, the Black Hills outcrops provide an important analog for the types of stratigraphic and sedimentologic relationships expected within the Inyan Kara sequences in the subsurface.

Workshop Basemap

Outcrop Localities

Drone-based earth models

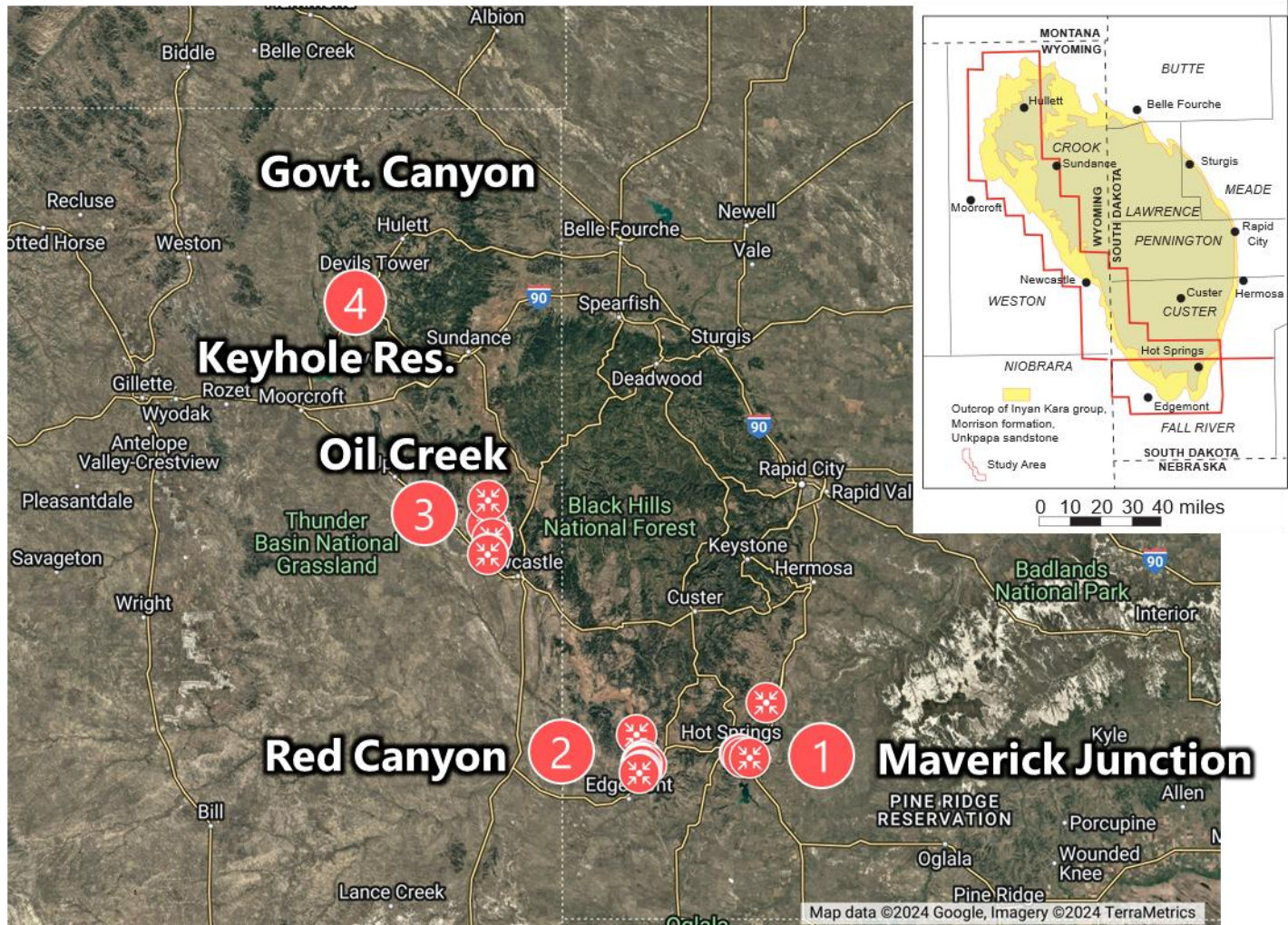


Figure 2. Basemap of study area, Landsat image of Black Hills, showing the locations of field trip stop areas (1-4) and selected 3D photogrammetry images (earth models). The workshop itinerary has been constructed to allow participants to examine the heterogeneity of the Inyan Kara Group from proximal to more distal settings, along an approximately 160 km long, SE-NW transect. Source: Google Earth, Landsat Image, Copernicus.

Example Earth Model

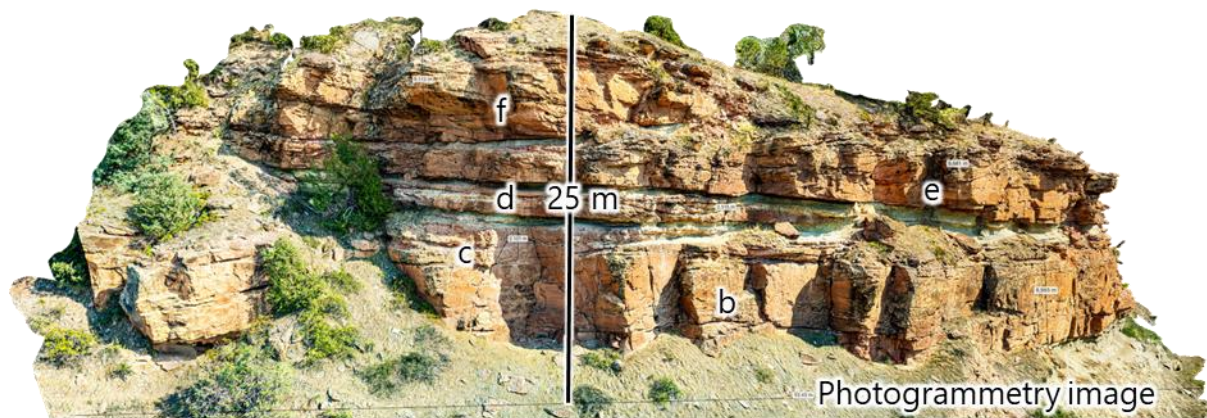


Figure 3. Example of earth model, Lakota Formation, Fall River County, SD. An extensive library of done-based, 3D photogrammetry images (earth models) of the outcrops will be available during the workshop. Each outcrop visitation is complimented by one or more 3D images. Others can be visited virtually.

Bios

Rick Beaubouef: has over 30 years of experience with a proven track record in the oil and gas industry. He's held various technical and leadership roles in E-D-P and Research/Technology at ExxonMobil and Hess. Rick has deep expertise in sequence stratigraphy and reservoir description and characterization in a variety of basins and settings. He is focused on integrated approaches where subsurface studies are complimented by outcrop geology, modern depositional systems, and knowledge of geologic processes. He is a teacher, coach, and mentor, but also an avid student of geoscience, and is passionate about his work. Visit rtbgeoscience.com

Chris Oswalt: has over two decades of experience in outdoor education and wilderness risk management. For six years, Christopher served as the Global Field Safety Director for Nautilus/RPS where he trained field staff, audited courses in the field, and oversaw complex safety protocols and operations for a portfolio of over 100 field courses worldwide. In 2019, he left Nautilus to launch his own company, Geology Field School, dedicating himself to running the highest quality field courses possible. He is a nationally Registered EMT, a member of Texas Search and Rescue (TEXSAR), and a certified FAA Part 107 drone pilot with 11 years of experience. Visit geologyfieldschool.com