Mineralogical Association of Canada, Short Course

Raymond Donelick[1], Cited References[1], Carslaw sr.[1], sr. Jaeger[1], and Chew sr.[1]

[1]Affiliation not available

December 18, 2023

Posted on 18 Dec 2023 — CC-BY 4.0 — https://doi.org/10.22541/essoar.170289984.40946248/v1 — This is a preprint and has not been peer-reviewed. Data may be preliminary.

AFT Study of a Dike Intrusion, Navajo Nation: A Junior High School Project

Kaelyn White[1], B. Craig[2], J. Begay[2], B. Klein[2], D.A. Foster[3], R. Donelick[4], Kevin D. Webster[2]

kaewhite@chinleusd.k12.az.us bcraig@dinecollege.edu dafoster@ufl.edu donelick@apatite.com kwebster@dinecollege.edu

Chinle Junior High School
Chinle, Arizona
The Navajo Nation
USA

Tsaile, Arizona
The Navajo Nation
USA

UNIVERSITY of FLORIDA

Apatite.com Partners, LLC

Abstract

A state-of-the-art mobile Apatite Fission Track (AFT) laboratory is operational at Diné College on the Navajo Nation. For outreach to local Junior High School students, AFT analysis was applied to samples related to a Tertiary dike intruded into Lower Jurassic Navajo Sandstone, near Boundary Butte, southern Utah, Navajo Nation. AFTs in the dike and adjacent reset sandstone constrain post-intrusion time-temperature (t-T) paths. AFTs in one nearby sample constrain heating due to dike intrusion to between 275-325°C (assuming 1-2 months duration). AFTs far from the dike constrain pre-intrusion and post-intrusion t-T paths.

Ms. White will provide several Chinle Junior High School 7th Grade students the AFT-based t-T histories summarized above and an Excel workbook containing Visual Basic source code that solves the infinite sheet heat flow equation (Carslaw and Jaeger's (1959, Equation 9, page 56). The students will be tasked with matching the AFT-based and heat-flow-equation-based t-T histories. Student and professional experiences with this project are being documented and will be polled. Lessons for students will reflect the Arizona Beyond Textbooks standards as an afterschool extracurricular project. The ultimate objective of this project is to demonstrate to these curious students links between AFT sciences and the rich natural history of the Navajo Nation.

Fieldwork on the Navajo Nation was conducted under a permit from the Navajo Nation Minerals Department. Any person(s) wishing to conduct geologic investigations on the Navajo Nation must first apply for and receive a permit from the Navajo Nation Minerals Department, P.O. Box 1910, Window Rock, Arizona 86515, USA, and Telephone No. +1 (928) 871-6587.

Figure 1. Sample localities (geology from Hintze and Stokes (1963).

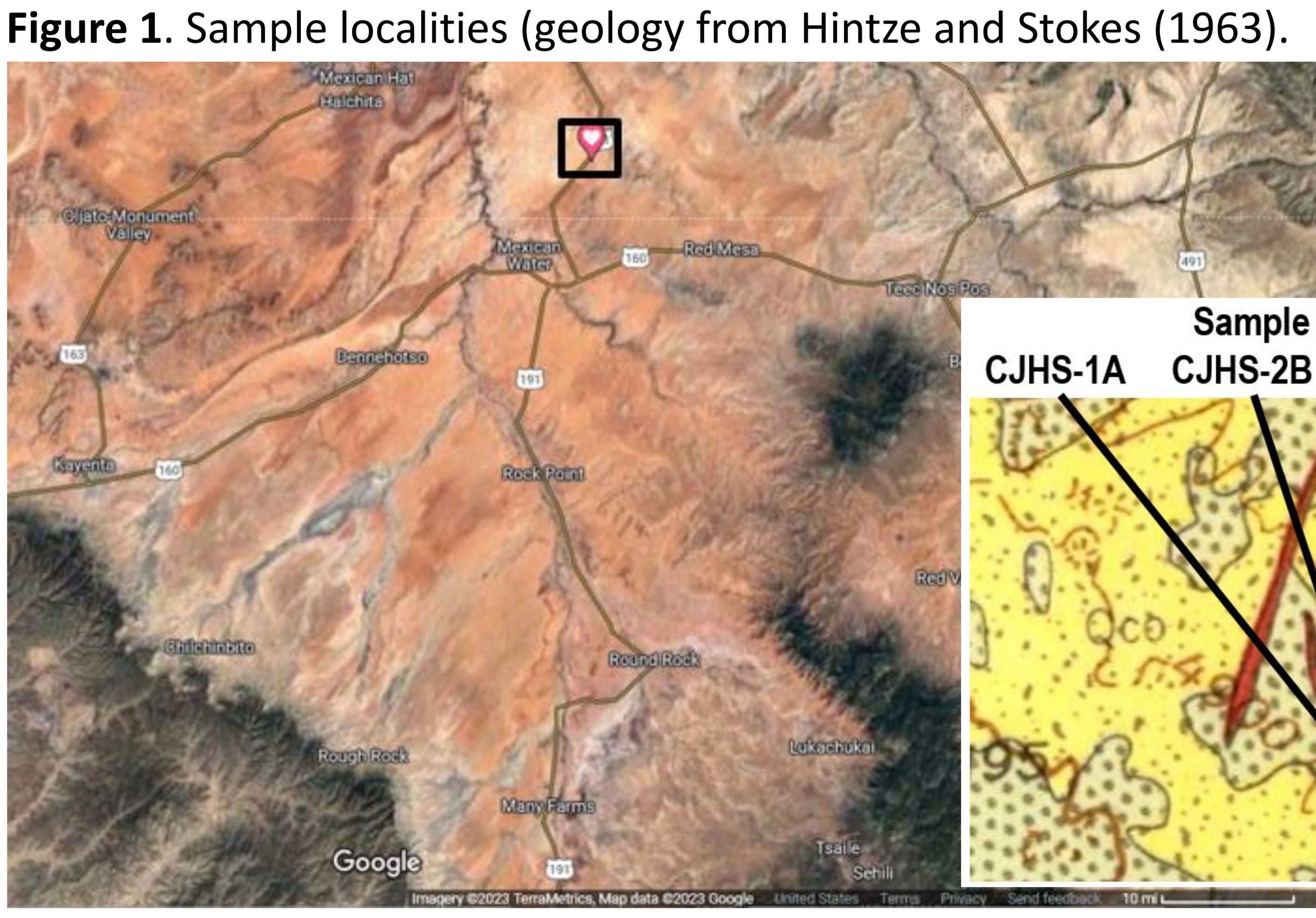


Table 1. AFT data summary (analyst Ray Donelick).

Sample Locality	Type	Strat Age (Ma)	N Ages All (grain)	N Ages ≈ 30 Ma (grain)	Pooled Age (95%CI) (Ma)	N Lengths (track)	Mean Length (1σ) (µm)
CJHS-1A	dike 0 m	Tertiary	48	44	23.0 (- 3.8 + 4.6)	22	14.83 (0.20)
CJHS-2A	sandstone 2 m	L. Jurassic	75	70	21.5 (- 3.2 + 3.8)	63	13.99 (0.15)
CJHS-3A	sandstone 3 m	L. Jurassic			next field trip		
CJHS-2B	sandstone 5 m	L. Jurassic	76	0	142.9 (-12.7 +13.9)	448	10.87 (0.12)
CJHS-3A	sandstone 20 m	L. Jurassic			next field trip		

Methods

The AFT samples were prepared for analysis following the detailed description of Donelick et al. (2005). AFTs were etched using 5.5N HNO_3 for 20 s at 21°C (Donelick et al., 1990). Apatite grains were selected and AFT data (ρ_s, CFT lengths, mean Dpar and Dper for host apatite grain) measured live (prior to digital recording) by Ray Donelick at Apatite.com Partners LLC laboratory in Viola, Idaho (Nikon E600 microscope, Ludl Kinetec XY-stage, ASI Z-drive, Lumenera Infinity1 digital camera, Apatite.com Partners' Sample_Scanner.py software). Apatite grains were reviewed and AFT data re-measured by analysts Benjamin Craig and Jayson Begay at Diné College Apatite Fission-Track (DCAF-T) laboratory in Tsaile, Arizona (Olympus BX60 optical microscope, ASI MS-2000 XY-stage, ASI Z-drive, Lumenera Infinity2 digital camera, Sample_Scanner.py software). CFT length measurements were enhanced using ^{252}Cf-derived fission fragment irradiation (Donelick and Miller, 1991). LA-ICP-MS data were collected by Ray Donelick and Ms. Kaelyn White at Washington State University Geoanalytical Laboratory using a NWR UP-213 laser (213 nm, 8 s warmup, 20 s ablation, 20 s washout, 25 µm diameter spot) and Agilent 7700 quadruple mass spectrometer (37 masses for 33 elements including P, Cl, Ca, REEs, Pb, Th, U). AFT ages (Donelick et al., 2005; Cogné et al., 2019), UPb ages (Chew and Donelick, 2012), and chemical compositions (Donelick and Donelick, 2014; Chew et al., 2014) were calculated using Apatite.com Partners' MSData software.

Results

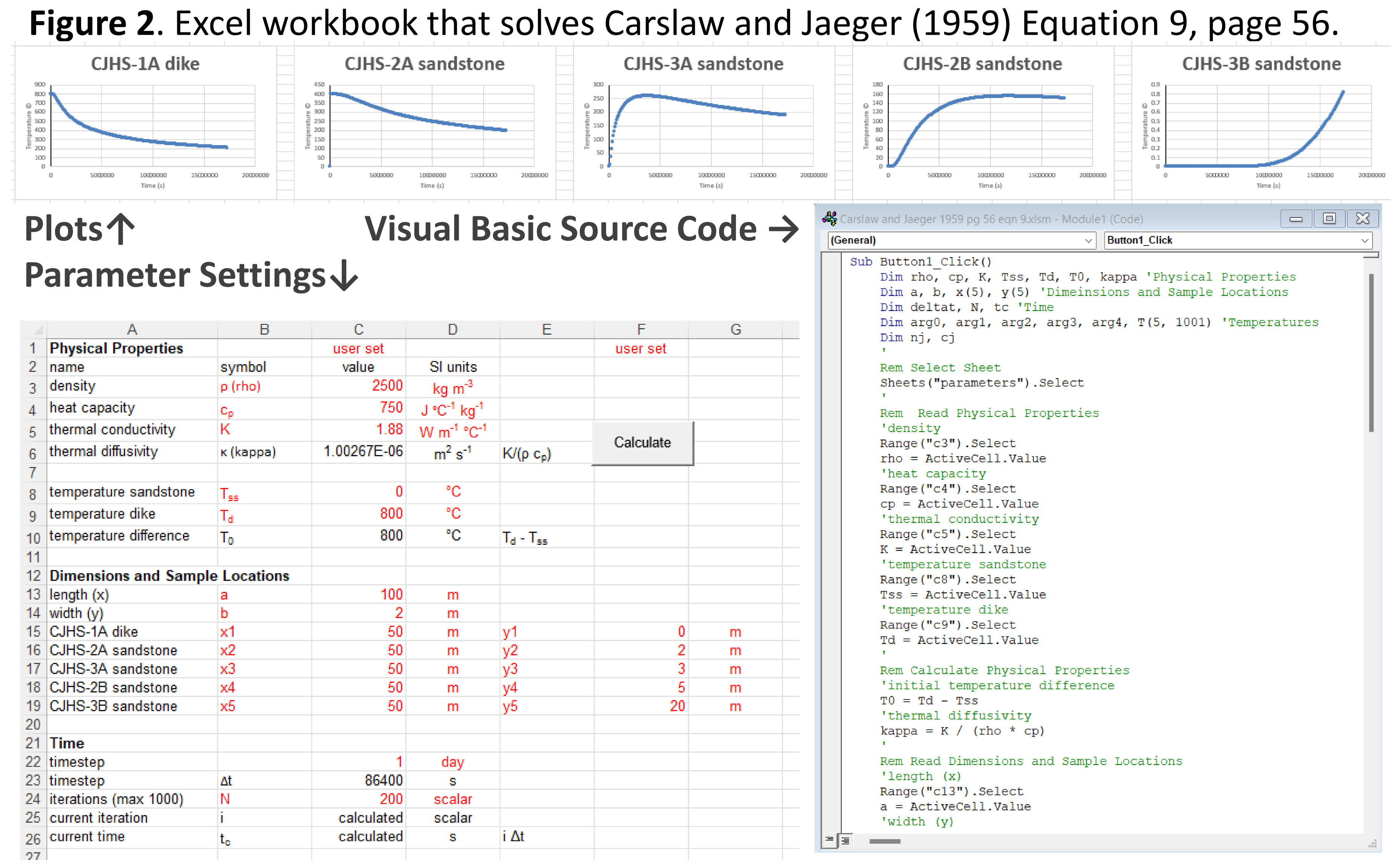
Sample localities are shown in **Figure 1**. AFT data are summarized in **Table 1**.

Junior High School Science Club Project

Due to COVID-19 restrictions, Ms. White's Science Club at Chinle Junior High School will begin this project in September 2023. This AFT study is intended to engage students with Science, Technology, Engineering, and Mathematics subjects. The students will receive background information that place the samples in their geological context. A second field trip to the sample site is planned for October 2023 so the students can view first-hand and measure field relations (dike width, distance of sandstone samples to the dike) and to collect additional rocks for further analysis (sandstone samples CJHS-3A and CJHS-3B). Students will receive scaffolded information about apatite fission track data and how time-temperature histories are predicted using those data. Additionally, students will receive an Excel file (**Figure 2**) with Visual Basic code that solves Carslaw and Jaeger's infinite sheet analysis equation (1959; Equation 9, page 56). The students will be tasked with learning and modifying this Visual Basic code and with matching the AFT-based time-temperature predictions. Lastly, students will receive ongoing guidance by experts whilst sharing enthusiasm about the fields of geology and geological heat flow. The ultimate objective of this project is to help curious students make the link between state-of-the-art data gathered for this project and the sciences used with the rich natural history of the Navajo Nation. It is hoped that the students enter this project in a Science Fair competition during Spring 2024.

Student and professional experiences with this project are being documented and will be polled. Lessons for students will reflect the Arizona Beyond Textbooks standards as an afterschool extracurricular project.

Figure 2. Excel workbook that solves Carslaw and Jaeger (1959) Equation 9, page 56.



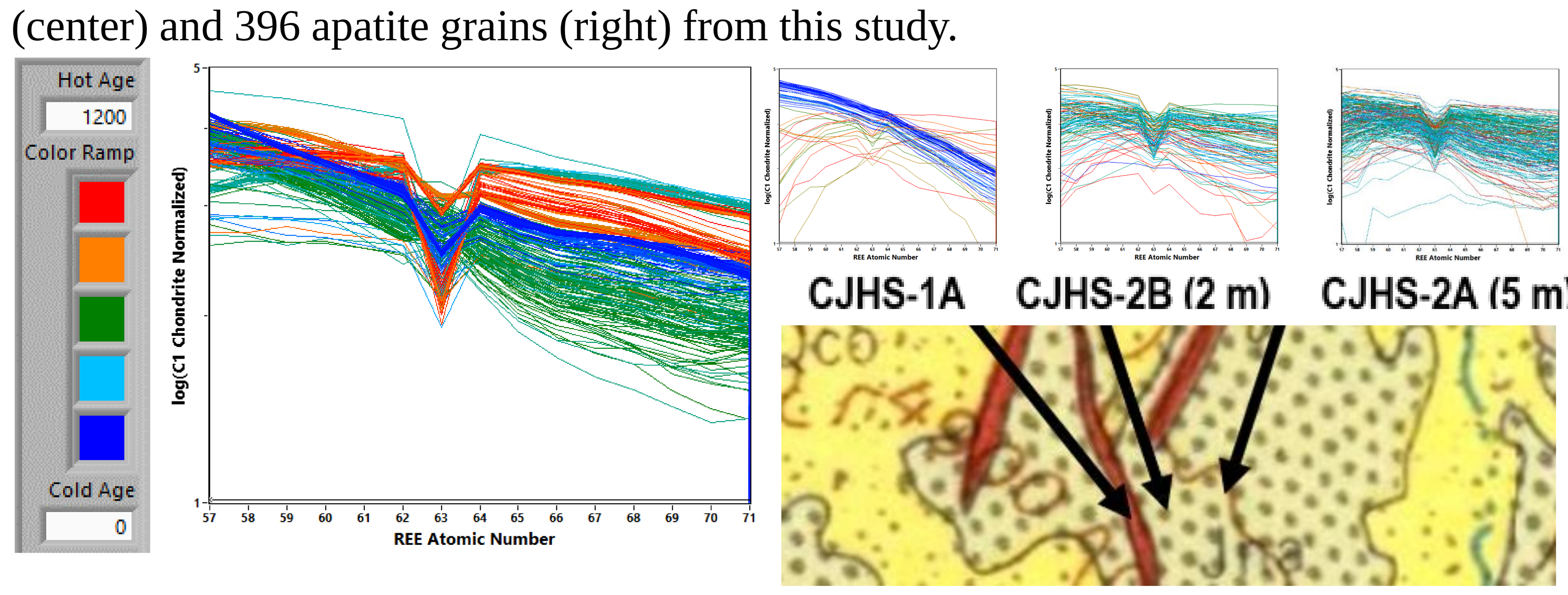
Professional Development for Teachers

AFT data (**Figure 3**) are fascinating and these data offer educators a low-cost science and mathematics connection to the land and culture of the Diné (Navajo) People.

Questions to Thermo 2023 Attendees:

1. Any Junior and Senior High School projects to share (such as Geobus, 2023)?
2. Would you collaborate with the DCAF-T laboratory on student projects?

Figure 3. Colored by apatite UPb age (left), REE profiles for 381 standard apatite grains (center) and 396 apatite grains (right) from this study.



References Cited

Carslaw and Jaeger, 1959: Conduction of Heat in Solids. Oxford
Chew and Donelick, 2012: Mineralogical Association of Canada, Short Course, v. 42, pp. 219–247
Chew et al., 2014: Geostandards and Geoanalytical Research, v. 38, pp. 23-35
Cogné et al., 2019 : Chemical Geology, v. 531, no. 119302
Donelick and Donelick, 2014: U.S. Patent Number 8,901,485
Donelick and Miller, 1991: Nuclear Tracks and Radiation Measurements, v. 18, no. 3, pp. 301-307
Donelick et al., 1990: Nuclear Tracks and Radiation Measurements, v. 17, no. 3, pp. 261-265
Donelick et al., 2005: RiMG, Mineralogical Society of America, v. 58, p. 49-94
Geobus, 2023: University College London, https://www.geobus-london.org.uk/
Hintze and Stokes, 1963: Utah Geological and Mineralogical Survey, 1:250,000