National Aeronautics and Space Administration

CT Scanning to Study Growth of a Simulated Hydrothermal Chimney

Principal Investigator: John Bescup (514); Co-Investigators: Laura Barge (322), Eduardo Martinez (322), Sam Avasapian (514), Laura Rodriguez (322), John-Paul Jones (346)

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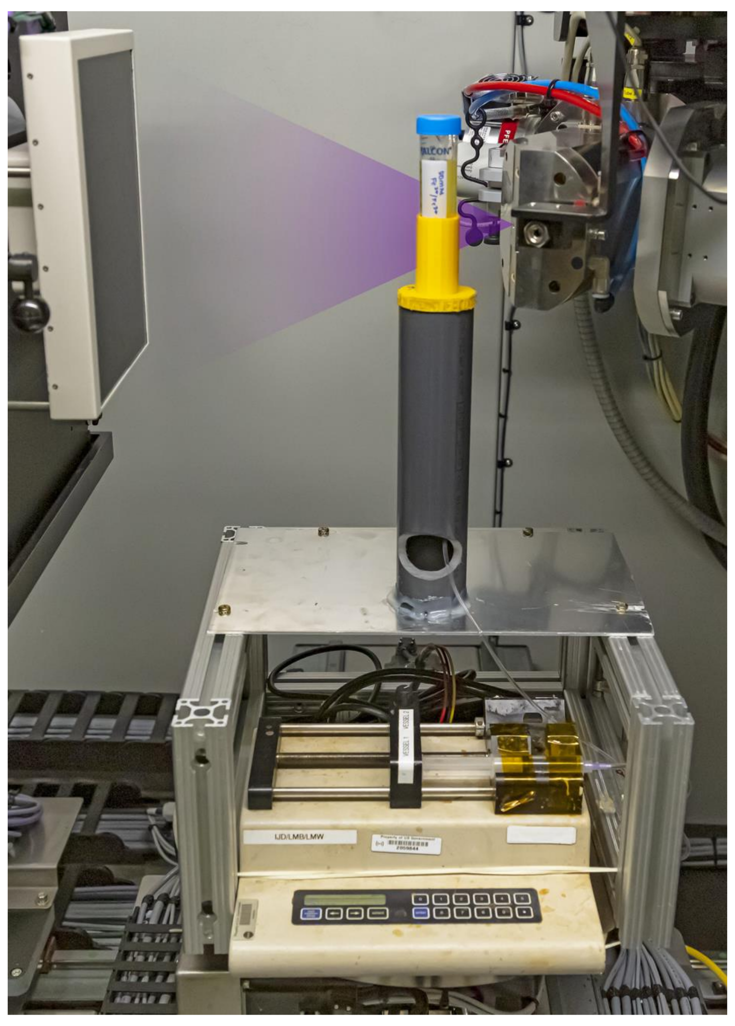

Fig.1: Photo of Experiment Setup

Objectives: 1.) grow a hydrothermal chimney analog inside a Computed Tomography (CT) instrument 2.) capture "4D" CT X-ray, producing a multitude of three-dimensional datasets as the structure evolves 3.) generate imagery of structural growth at selected intervals of interest and 4.) use CT post-processing software to measure wall thickness and simulate/visualize the pressure/velocity of fluid within the structure.

Background: Hydrothermal vents are locations where seawater chemically reacts with ocean crust, re-emerging at cracks in the seafloor to interface with the seawater, precipitating mineral "chimney" structures. The environment surrounding these structures is supplied with heat and nutrients, fueling ecosystems of extremophiles. It has been postulated that hydrothermal vents may be a potential location where life arose on planet Earth. Other ocean worlds within our solar system may currently have similar hydrothermal systems, and it has been theorized they may have existed on early Mars. Due to the many challenges of studying these vents within our oceans, work has been performed to recreate & analyze them in a laboratory environment.

Fig.2: Photo of final vent structure

Approach & Results: Three distinct chemistries representing early Earth were synthesized: Iron-Hydroxide, Iron-Silicate, & Iron-Sulfide. Low kV X-ray was used for greater contrast (100kV), as well as stability. Typically, CT scans are acquired with stop-motion of the stage; continuous-motion was used in this study to ensure no damage or influence on the formation of the chimney occurred.

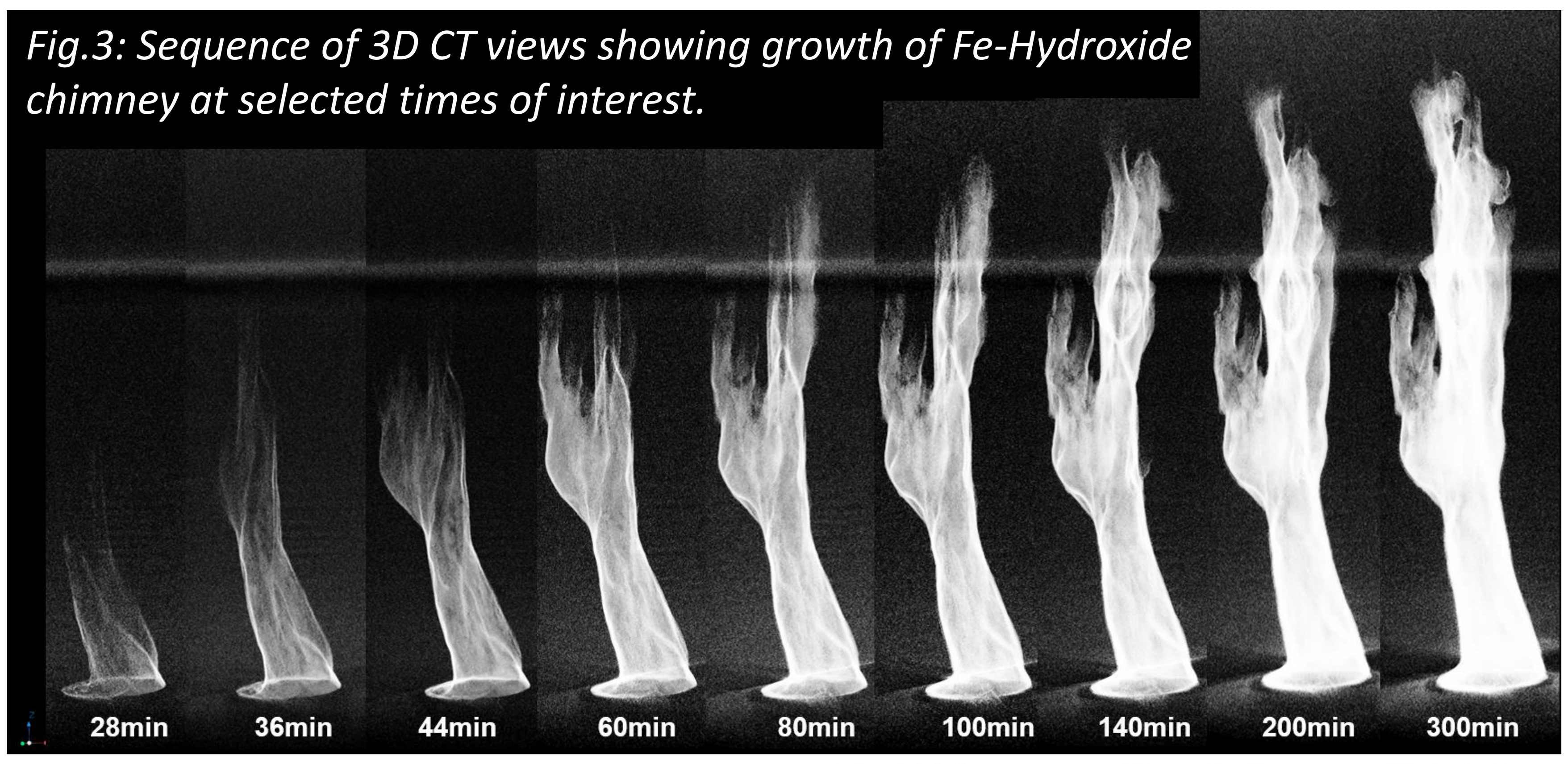

Fig.3: Sequence of 3D CT views showing growth of Fe-Hydroxide chimney at selected times of interest.

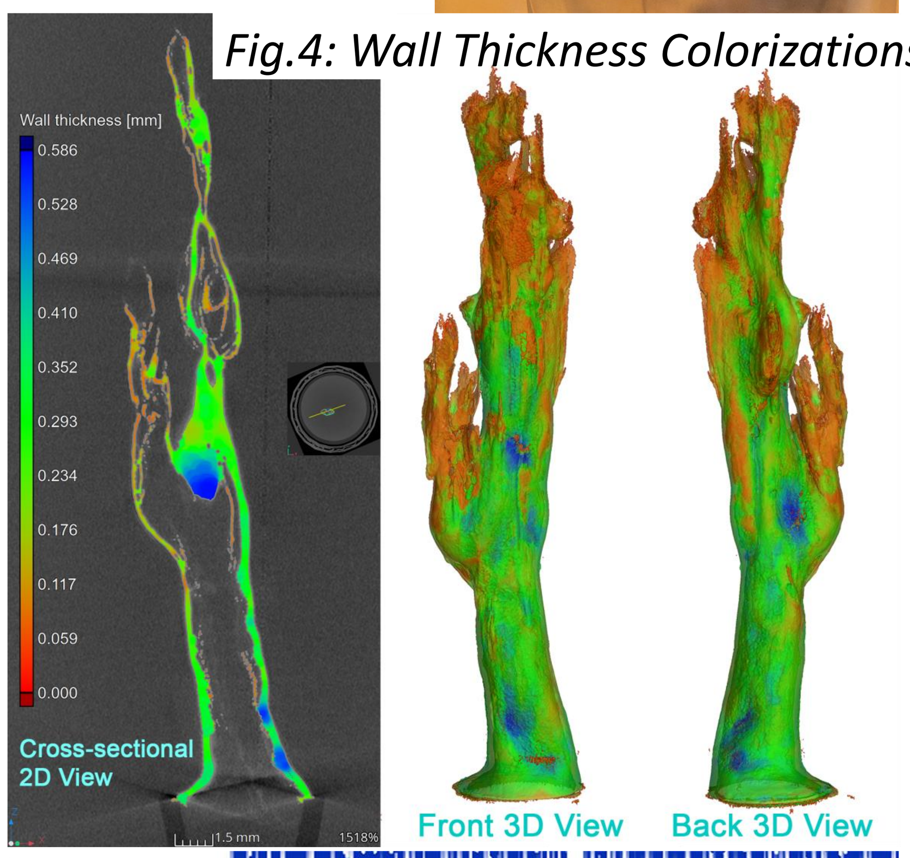

Fig.4: Wall Thickness Colorizations

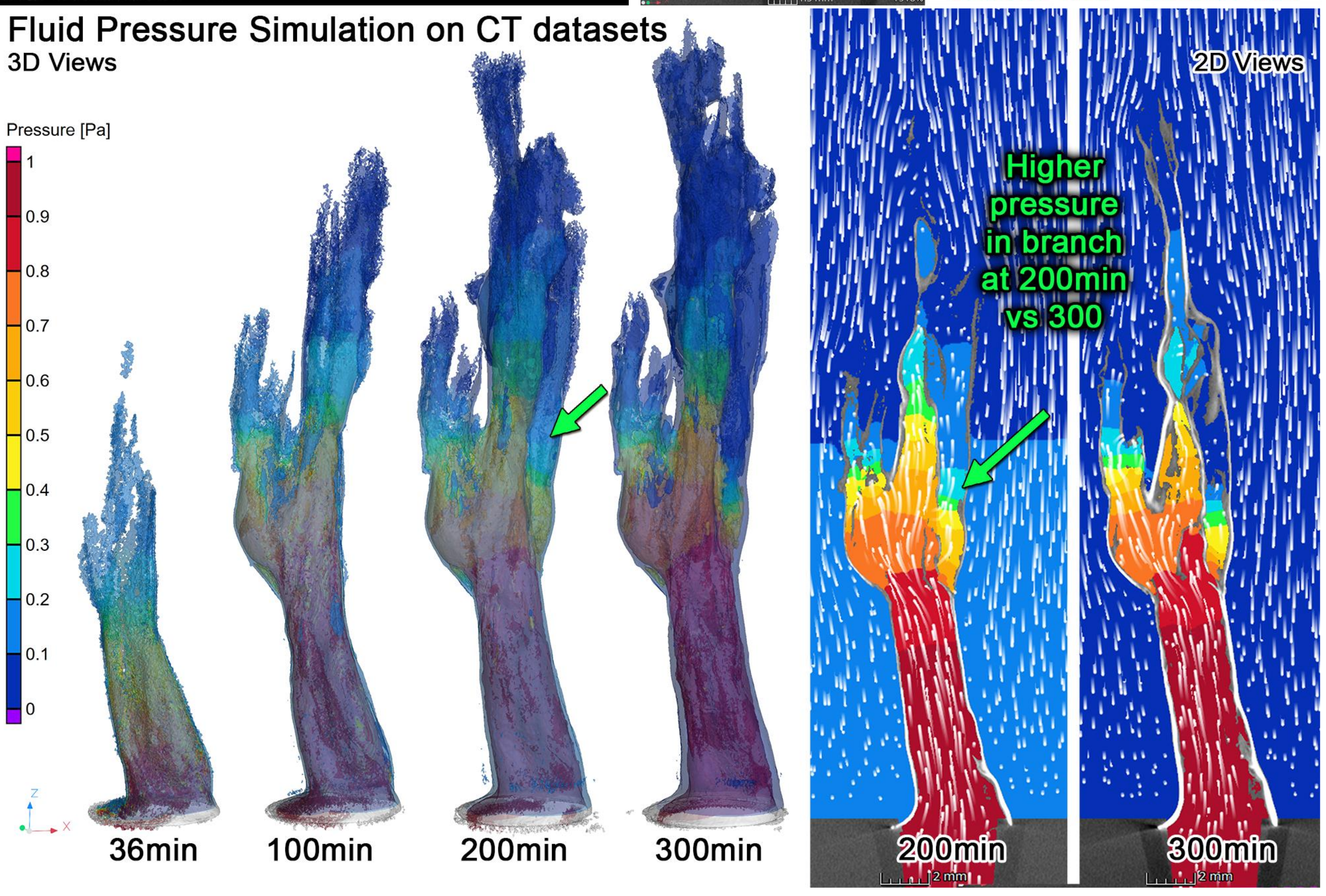

Fig.5: Fluid Pressure Simulation on CT datasets

56,252 radiographs were reconstructed into 75 time-intervals, yielding 3D datasets of the structure every 4 minutes, which were then compiled into image sequences (Fig.3) & time-lapse video, showing the growth of the vent from an orbiting 3D perspective. Volume Graphics VGStudioMAX CT post-processing software was used to automatically compute the wall thickness (Fig.4) of each vent chemistry and the Absolute Permeability function of the Transport Phenomena Simulation add-on module was used to simulate fluid flow through the vent structure at 3-5 points of interest for each vent (Fig.5). An interesting finding in this data is that one arm of the Iron-Hydroxide vent shows reduced pressure and fluid velocity as time increased, indicating that passageway may have stagnated, creating a closed-off space within the vent.

Significance/Benefits to JPL and NASA: Understanding the growth process of hydrothermal vents helps to inform origin of life theories for both Earth and other ocean worlds such as Europa or Enceladus. In particular, understanding the way that pores within the chimney may form, or how the fluid flow may stagnate within areas of the chimney, has implications upon the habitability for microbes within those portions of the overall structure. Greater visibility into the internal composition of hydrothermal chimneys can help inform scientists hypothesizing about the potential for life to arise in hydrothermal sites and provide context for biosignature investigations or instrumentations in ocean worlds missions in the decades ahead.

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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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PI/Task Mgr. Contact Information:
Email: John.Bescup@jpl.nasa.gov