# Jeff Wadsworth: Probed how Damascus steel swords made

**(As published in *The Oak Ridger's Historically Speaking* column on May 12, 2014)**

As Carolyn Krause continues to bring us superb insights into some of the key leaders of the Oak Ridge National Laboratory, she has delved into the past to bring forward some astounding facts about Jeff Wadsworth, the metallurgist. He, being intrigued by the past art of sword making, learned the secret of the steel used in a most effective hand to hand combat weapon, the Damascus sword.

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Al Trivelpiece pedals his unicycle without losing his balance. Bill Madia drives his motorcycle on Bethel Valley Road. In a demonstration Jeff Wadsworth splits a silk scarf midair using an ancient Damascus steel sword. These are my occasional visions of the past three directors of Oak Ridge National Laboratory.

In September 1981 Wadsworth's metallurgical research at Stanford University was beginning to pay off. He and Oleg Sherby, a professor at Stanford and an authority on deformable metals, published a notable paper in the British scientific journal "Progress in Materials Science."

Even better, renowned science writer Walter Sullivan highlighted their research in his article "The Mystery of Damascus Steel Appears Solved" in the Sept. 29, 1981, issue of The New York Times.

At one of the metallurgists' presentations on their high-carbon steel, a sword enthusiast noted that Damascus steel was also rich in carbon. So, Sherby and Wadsworth decided to compare the composition of their own steel with that of ancient Damascus steel used for swords, shields and armor and prized for their wavy, watery "damask" patterns.

Their research focused on developing an ultra-high-carbon (UHC) "superplastic" steel that can be readily shaped into forms as complex as gears for cars. UHC steels would minimize the need for machining, reducing manufacturing costs. Their studies, Wadsworth told Sullivan, had shown how to make steel even more amenable to shaping than the Damascus variety. However, UHC steels are less weldable than ordinary steels.

Cast iron is high in carbon (> 2.14 percent) but ordinary steel contains only a fraction of 1 percent carbon. But Wadsworth and Sherby developed steels that are 1 to 2 percent carbon. They found that Damascus steel had properties almost identical to those of their new superplastic steels, even though the new steel had been produced by contemporary methods.

Wadsworth, who served as director of ORNL from 2003 to June 2007, gave three classes on the history of Damascus steel in 2004 at the Oak Ridge Institute for Continued Learning. The retirees in his course learned that steel was produced for weapons as early as the fourth century B.C. when Alexander the Great created one of the largest empires of the ancient world.

According to the Times article, Wadsworth and Sherby "seeking to produce a 'superplastic' metal, appear to have stumbled on the secret of Damascus steel, the legendary material used by numerous warriors of the past. Its formula had been lost for generations.

"The remarkable characteristics of Damascus steel became known to Europe when the Crusaders reached the Middle East, beginning in the 11th century. They discovered that swords of this metal could split a feather in midair, yet retain their edge through many a battle with the Saracens."

Damascus steel weapons were also used in trench warfare during World War I.

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In his ORICL course Wadsworth said that the Arab makers of Damascus steel weapons shared the steel-manufacturing method but kept it secret from non-Arabic competitors for eight centuries. By the 14th century when firearms were first in use, the secret was lost. The Russian metallurgist Pavel Anossoff tried unsuccessfully to rediscover the method for making the steel he knew as "bulat."

In 1841 Anossoff declared: "Our warriors will soon be armed with bulat blades, our agricultural laborers will till the soil with bulat plow shares. . .Bulat will supersede all steel now employed for the manufacture of articles of special sharpness and endurance."

In Damascus blade production, the steel was forged and hammered in shape at a relatively low temperature, reheated and then rapidly cooled, or quenched, to confer magical properties in the alloy.

The ancient steelmakers believed that the key to the best blades was quenching the steel in special fluids, such as "dragon blood," "donkey urine" and the urine of a "three-year-old goat fed only ferns for three days."

According to manuscripts from Asia Minor, a Damascus sword must be heated until it glows "like the sun rising in the desert." It then should be cooled to the color of royal purple and plunged "into the body of a muscular slave" to transfer his strength to the sword. Although the homicidal quenching techniques were based on superstition, they may have contributed to the method's success by adding nitrogen to the alloy, the Times article stated.

Most Damascus steel was derived from blocks of "wootz," a form of steel produced in India. It is malleable when heated but extraordinarily tough when cooled. Michael Faraday, the famous British scientist and son of a blacksmith, sought unsuccessfully to determine the composition of wootz.

Wootz was apparently prepared in crucibles containing cakes of porous iron, as well as wood or charcoal to enrich the iron in carbon. A critical factor, Wadsworth told Sullivan, may have been the processing of wootz at temperatures as high as 2,300 degrees.

After being held there for days, wootz was cooled to room temperature over a day or so. It was then shipped to the Middle East for relatively low-temperature fabrication. The moderate heat preserved enough iron carbide (the mating of three atoms of iron to a carbon atom) to give the blades great strength, yet not enough to make them brittle. The large carbide grains are responsible for the blades' typical watery pattern.

The superplastic steel developed at Stanford in the 1980s was kept at high temperature for only a few hours. It was shaped during cooling, reheated to moderate temperature for further working and then quenched to achieve extreme hardness. This process, Wadsworth told the Times, produced tiny carbide grains, making the new steel even harder and more ductile than Damascus steel.

Just think. If his teacher had not had the vision that Wadsworth was capable of learning and loving the science of metals in college, the former ORNL director and current president of Battelle might never have succeeded as a metallurgist and manager of large scientific organizations.

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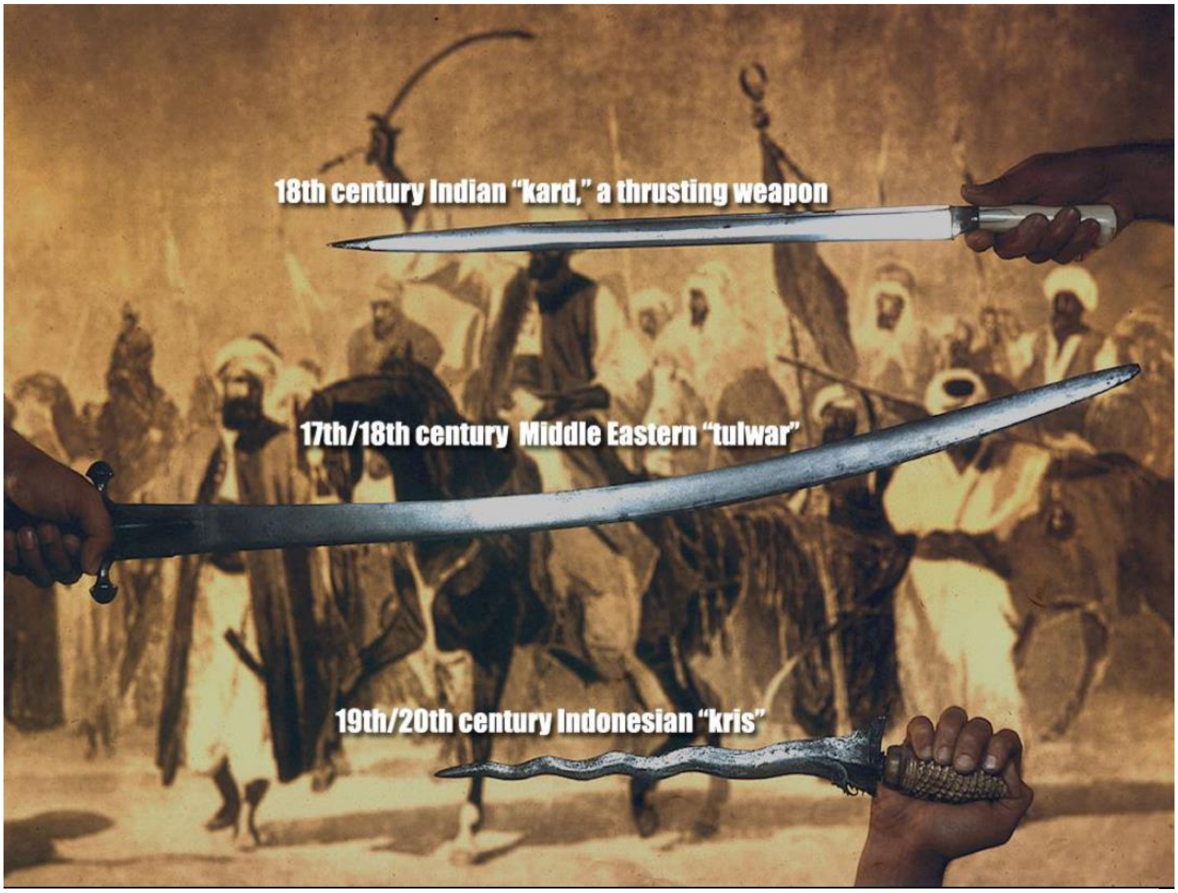
Thank you Carolyn!  Now what do you think about that.  Only in Oak Ridge would someone with experiences as amazing as Jeff Wadsworth's metallurgical discoveries be considered just another discovery. He is among many others who continually discover new scientific details that literally are changing the way we live.

Oak Ridge, the name that stands alone. Be proud of our leaders such as Jeff Wadsworth. Be proud of the discoveries of our scientists and engineers. We are changing the world!




Examples of ancient swords studied by Jeff Wadsworth in his quest to understand and duplicate the Damascus steel

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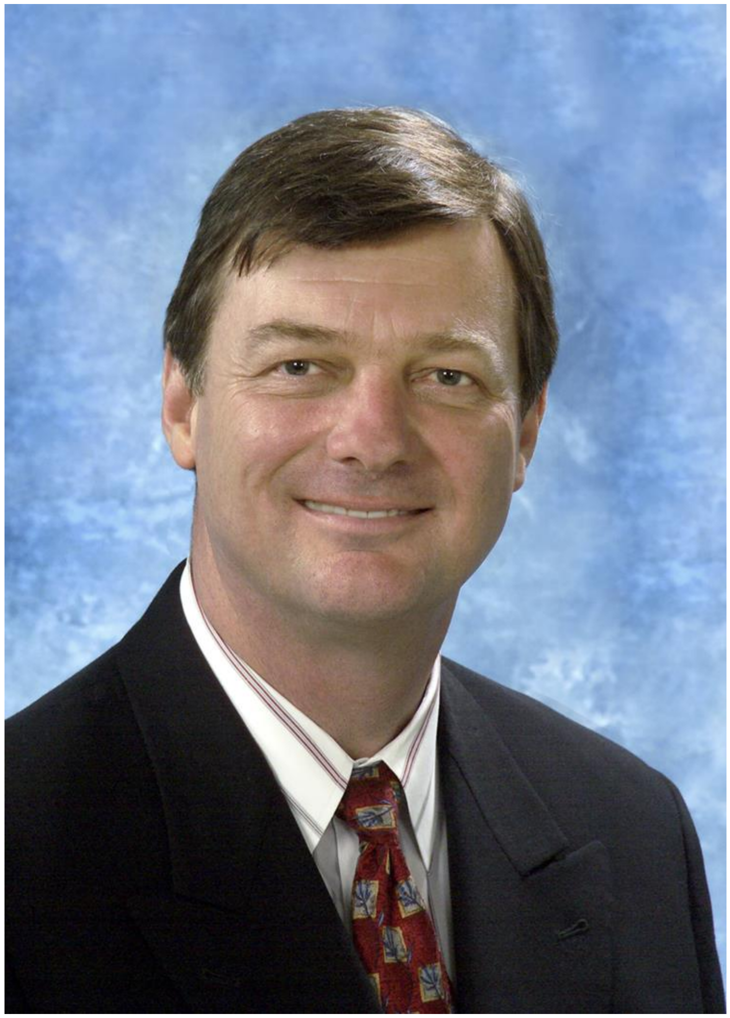

Jeff Wadsworth, metallurgist with an unusual quest